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THE HELOTIALES OF THE MUSSOORIE HILLS—I

BY K. S. THIND AND PRITAM SINGH

Botany Department, Panjab University, Chandigarh-3

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THE taxonomic study of the Helotiales of the Mussoorie Hills is a part of the study of fungus flora of that region undertaken by the senior author and his students. This first paper deals with 8 species of Helotiales, of which 6 are new records for India. The fructifications have been described from the fresh material supplemented with dried as well as with formalin-alcohol preserved specimens.

The numbers of the species are the serial numbers of the Helotoid flora.

The collections have been deposited in the Herbarium of the Panjab University. Duplicate material, dry and in formalin-alcohol, is in the U.S. National Fungus Collections, Beltsville, Maryland, U.S.A.

This interesting and a beautiful order of fungi has remained neglected so far in India. Butler and Bisby (1931) have listed about twenty species of Helotiales. Cash (1948) described one species of Helotiales which was collected from India by Sultan Ahmad. There is apparently no other report of any species of Helotiales. Accordingly, it is our aim to carry on the taxonomic study of Indian Helotiales comprehensively from this laboratory.

1. ***Cyathicula coronata*** **(Bull. ex Fr.) de Not.** in *Karst. Fungi Fenn. Exsie.*, 146, 1865.

Apothecia 1–2 mm. in diameter and 1·5–3 mm. in height, scattered to gregarious, globose when young, shallow-cupulate later on, finally expanded, regular, cream coloured to pale yellow to yellow, on drying becoming deeper and brighter coloured, fleshy, very minutely tomentose, stipitate; external surface cream coloured to light yellow, minutely tomentose, even; excipular cells $2 \cdot 7$–$6 \cdot 3\,\mu$ wide, subhyaline, linear-elongated, pseudoparenchymatous, very slightly thick-walled; margin beset with several long sharp-pointed teeth which are nothing else but pyramidal clusters of closely packed or somewhat agglutinated excipular cells; hymenium concolorous with the external surface, smooth, concave; stipe 1–2·5 mm. long, cylindric, concolorous with the external surface, minutely tomentose, solid, even; teeth 140–$245 \times 17 \cdot 5$–$19\,\mu$,

just bristle-like projections of the margin, sharp-pointed, rigid, erect, turned inward, and tapering above, composed of agglutinated hyphae or cells of excipulum. *Asci* 74–97×6·3–9·9 μ, cylindric-clavate, apex rounded, tapering below gradually into a stem-like base, do not turn blue with iodine solution, inoperculate. *Ascospores* 14·2–17·2× 2·6–4·5 μ, 8 in number, biseriate to irregularly uniseriate, ends overlapping, oblique to parallel, hyaline, fusoid-elongate, 1-septate, smooth, aguttate. *Paraphyses* 90–108×1·8–2·7 μ, filiform, hyaline, non-septate, simple, apex not enlarged. Text-Fig. 1, A–C.

Collected on dead twigs of herbaceous Phanerogams (Composita), The Municipal Garden, Mussoorie, September 11, 1956, **310**.

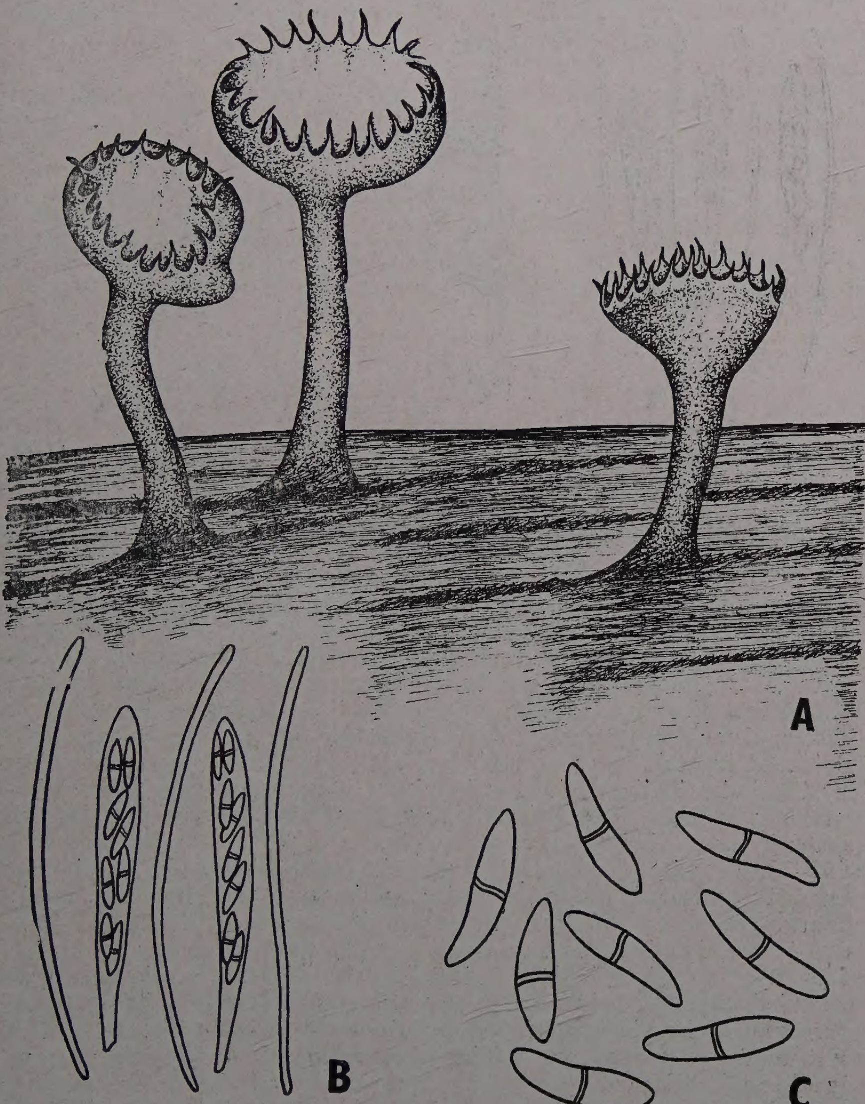
2. ***Helotium scutula* (Pers. ex Fr.) Karst.** in *Not. Sallsk. Faun. Flor. Fenn.*, **11:** 233, 1870.

Apothecia 1–3·5 mm. in diameter, gregarious to densely gregarious to crowded, at first concave, soon becoming strongly discoid with convex hymenium, regular at first, later on regular to irregular due to lobed margin, fleshy, slightly tough, creamy brown, stipitate; external surface deeper coloured than the hymenium, very finely tomentose; excipular cells 6·3–14·4 μ wide, hyaline individually, subhyaline to pale brown in a mass, rectangular, pseudoparenchymatous, very slightly thick-walled; margin smooth at first, later on becoming irregular and lobed, lobes mostly small, strongly out-turned at maturity; hymenium concave at first, strongly convex soon, smooth, creamy brown; stipe long, 1·5–4 mm. long and 343–525 μ wide, cylindric, finely tomentose or finely hispid, concolorous with the external surface but brown or darker at the base; pubescent hairs 16·2–47×2·7–4·5 μ, abundant, short, adpressed or erect, straight to mostly flexuous, mostly simple, sometimes branched, septate, apex rounded, light brown to brown. *Asci* 88–119×8–10·8 μ, clavate, apex rounded, tapering below into a short stem-like base, do not turn blue with iodine, inoperculate. *Ascospores* 18–21·7×4·5–6 μ, 8 in number, irregularly biseriate above and uniseriate below, oblique to parallel, ends overlapping, fusoid, usually slightly curved, simple, smooth, ends rounded but narrowed, aguttate, hyaline. *Paraphyses* 106–132×1·2–2·1 μ, filiform, non-septate, hyaline, simple, not enlarged at the top. Text-Fig. 2, A–C.

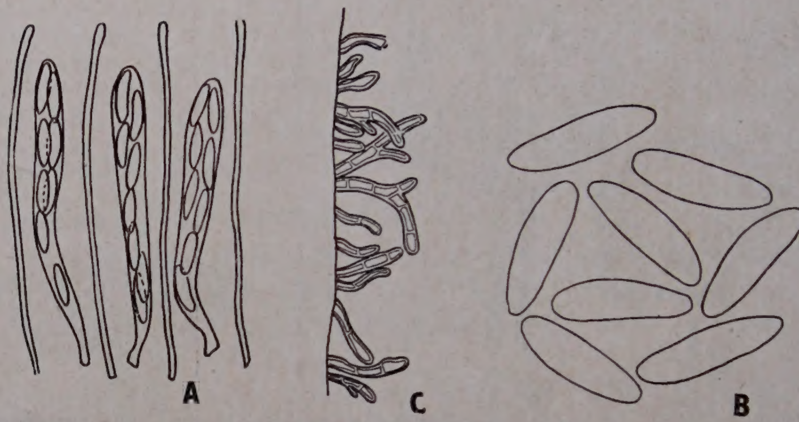
Collected on dead twigs of an Angiosperm (a Compositae), The Municipal Garden, Mussoorie, September 11, 1956, **311**.

This fungus belongs to *Helotium scutula* (Pers.) Karst., although differs from it in the following few respects:—

H. scutula	*Mussoorie fungus*
1. Pale yellow in colour	Creamy brown
2. Spores often spuriously 1–3 septate	Spores non-septate
3. Spores 20–28 × 3–4 μ	Spores 18–21·7 × 4·5–6 μ
4. Spores possess occasionally a cilium at one or both ends	Spores possess no cilium at all
5. Paraphyses up to 7 μ wide.	Paraphyses up to 2·1 μ wide.



TEXT-FIG. 1. *Cyathicula coronata* (Bull. ex Fr.) de Not. A. Apothecia, ×20. B. Asci and paraphyses, ×400. C. Ascospores, ×960.



TEXT-FIG. 2. *Helotium scutula* (Pers ex Fr.) Karst. A. Asci and paraphyses, ×400. B. Ascospores, ×950. C. Hairs, ×400.

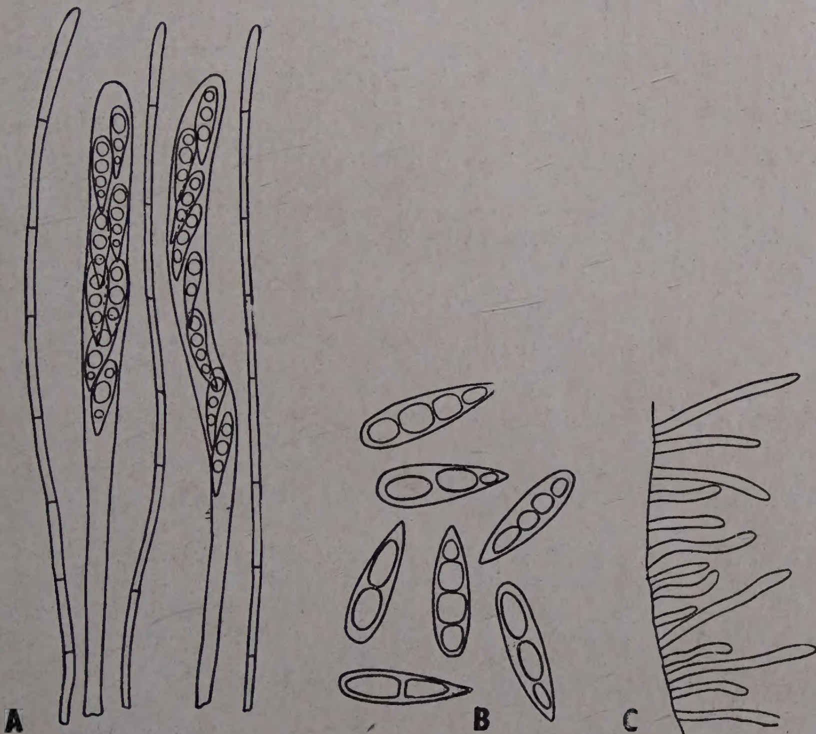
3. *Helotium fructigenum* (Bull. ex Fr.) Fuckel. *Symb. Mycol.*, 314, 1870.

Apothecia 0·7–1·4 mm. in diameter and 0·9–3·2 mm. in height, singly, gregarious to densely gregarious, globose and closed when young, soon expanding and becoming shallow cupulate, finally discoid, regular, white to cream coloured, on drying changing to light brown, soft and fleshy, smooth, stipitate; flesh concolorous and unchanging on exposure; taste and smell in particular; external surface concolorous to very light coloured, smooth, even; excipular cells 19·8–34×5·4–8·1 μ, rectangular, hyaline individually, subhyaline in a mass, thin-walled, pseudoparenchymatous; margin entire, smooth, hymenium white to cream coloured, smooth, even, slightly concave to plane; stipe 0·7–3 mm. long and 190–380 μ wide, concolorous with the external surface, cylindric, expanding abruptly above into the apothecium, very inconspicuously tomentose, even, soft and fleshy, solid; tomentose hairs 7·5–30×1·5–2·2 μ, abundant, hyaline, singly, simple, non-septate, short, hypha-like, apex round and blunt. *Asci* 77·4–90×6·3–8·1 μ, clavate, apex rounded, tapering below into a somewhat long stem-like base, do not turn blue with iodine, inoperculate. *Ascospores* 12·6–16·2×2·7–3·9 μ, 8 in number, uniseriate to irregularly biseriate, ends overlapping, narrowly ellipsoid or fusoid, hyaline, one end round and the other pointed, smooth, multiguttulate. *Paraphyses* 99–113×1·8–2·1 μ, hyaline, slender, filiform, septate, simple, not very inconspicuously enlarged at the top. Text-Fig. 3, A–C.

Collected on dead nuts of oak, etc., under Oak Forest, The Municipal Garden, Mussoorie, September 8, 1957, **312**.

This fungus has been collected only on dead acorns (nuts) of *Quercus incana* Roxb. and it undoubtedly belongs to *Helotium fructigenum* (Bull.) Karst. The presence of dense tomentum on the stipes

of the fungus is not mentioned in Seaver's (1951) *North American Cup-fungi* (*Inoperculates*).



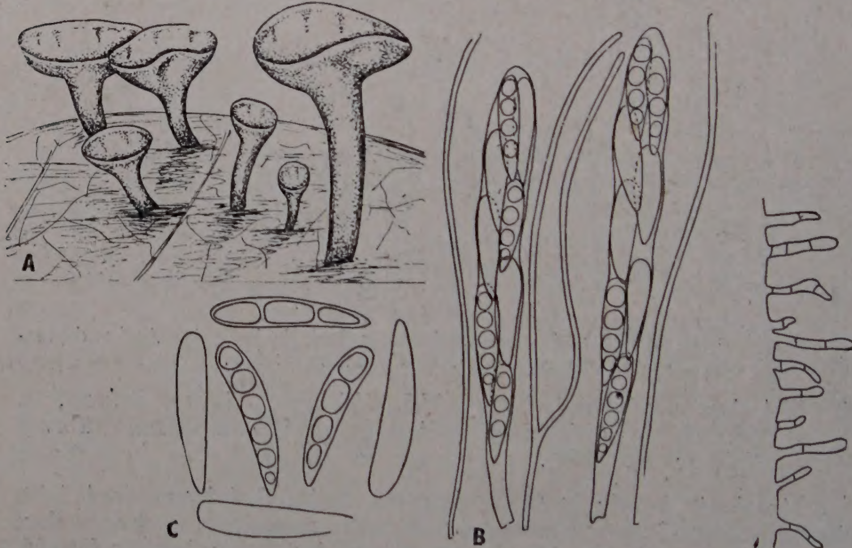
TEXT-FIG. 3. *Helotium fructigenum* (Bull. ex Fr.) Fuckel. A. Asci and paraphyses, ×950. B. Ascospores, ×1150. C. Hairs, ×950.

4. *Helotium caudatum (Karst.) Vel.,** *Monogr. Discom. Bohem.*, **1:** 206, 1934 (= *Helotium naviculasporum** Ellis in *Bull. Torrey Club*, **5:** 46, 1874).

Apothecia 0·8–1·6 mm. in diameter and 0·9–6·9 mm. in height, singly, scattered to gregarious to densely gregarious, globose when young, then extending and becoming shallow cupulate and finally discoid, regular. cream to pale yellow to yellow, soft and fleshy, almost smooth, stipitate; flesh concolorous with the external surface and unchanging on exposure; taste slightly bitter; smell in particular; external surface dirty white to cream coloured to pale yellow, lighter coloured than the hymenium, becoming yellowish brown on drying, smooth, even; excipular cells 14·4–36×7·2–21·6 μ, hyaline individually and subhyaline in a mass, rectangular, thin-walled, pseudoparenchymatous; margin

* According to White, 1943, *Helotium naviculasporum* Ellis is a synonym of *Helotium caudatum* (Karst.) Vel. Evidently, this position has been accepted by Dennis, 1956.

smooth, entire; hymenium smooth, even, cream to creamy yellow to yellow, deeper coloured than the external surface, slightly concave when young and plane in mature apothecia; stipe $0 \cdot 4$–$5 \cdot 3$ mm. long and 114–304 μ wide, white, dark at the base, much lighter coloured than the external surface, quite long, cylindric, expands abruptly into the apothecium, very minutely inconspicuously tomentose, soft and fleshy; tomentum $18 \cdot 9$–$46 \cdot 8 \times 1 \cdot 4$–$5 \cdot 4\ \mu$, hyaline, singly, simple, short, flexuous and hypha-like, 1–3 septate, apex round and blunt, base simple. *Asci* 76–$91 \times 6 \cdot 3$–$9\ \mu$, clavate, apex round and narrowed, tapering below gradually into a stem-like base, asci often and very slightly bulging against the ascospores, not turning blue with iodine, inoperculate. *Ascospores* 189–$23 \cdot 4 \times 2 \cdot 7$–$4 \cdot 5\mu$, 8 in number, irregularly biseriate, ends overlapping, hyaline, cylindric, upper end round and the lower one is narrowed, mostly curved, smooth, non-septate, multi-guttulate (3–6) when young, guttules small and round and of unequal size, aguttate when mature. *Paraphyses* 99–$126 \times 1 \cdot 4$–$1 \cdot 8\ \mu$, hyaline, filiform, non-septate, simple or branched, scarcely enlarged at the top. Text-Fig. 4, A–D.



TEXT-FIG. 4. *Helotium caudatum* (Karst.) Vel. A. Apothecia, ×20. B. Asci and simple to branched paraphyses, ×950. C. Ascospores, ×1150. D. Tomentose hair from the stipe, ×400.

Collected on the midribs and main veins of dead and decaying leaves of some Angiosperms under Oak Forest, The Cemetery, Camel's Back, Mussoorie, August 14, 1957, **313**.

This fungus belongs to *H. caudatum* (Karst.) Vel. but differs from it in having longer stipe of the apothecia, slightly narrower asci, and slightly narrower ascospores. Perhaps these minor differences fall within the normal range of variation of the species.

5. ***Bulgaria* inquinans* (Pers. ex Hook.) Fr.** in Brogniart, *Mycologie.* (*Bot.*) *Dict. Sci. Nat.*, **33**: 572, 1824 [(= *Phaeobulgaria inquinans*) (Pers.) Nannf. in *Nova Acta Soc. Sci. Upsal.*, Ser. **8**: 311, 1932].

Apothecia up to 2·6 cm. in diameter (mostly more than 1 cm.) and up to 2 cm. in height, gregarious to scattered, singly to caespitose, at first globose to short-cylindric, expanding, opening, elongating and finally becoming turbinate with the hymenium at first concave, later becoming plane and finally convex with the margin repand (in other words apothecia at first shallow cupulate, finally repand or discoid), sessile at first, stipitate at maturity, at first yellowish brown, later on dark brown, tough, somewhat leathery, gelatinous within, somewhat rough; external surface dark yellowish brown to dark brown to brownish black, tubercled or covered over with granular, irregular, polliculose, barky, tough, scale-like projections; excipular cells roundish to ovoid to angular, pseudoparenchymatous, thin-walled; margin smooth, entire, inturned in young apothecia and outturned in very mature ones; hymenium concave at first, later on plane to convex, at first brown, then dark brown and finally jet black, tar-like, and shining, perfectly smooth and soft; stipe 0·8–1·2 cm.×2–8 mm., cylindric, like the stem of a funnel expanding above into the apothecium, concolorous with the external surface throughout, rough or tubercled like the external surface but tubercles more prominent at the base. *Asci* 83–115× 6·3–10·8 μ, clavate, apex rounded, tapering below into a long stem-like base, narrow, conspicuously bulging out against the spores, not turning blue with iodine, inoperculate. *Ascospores* 8·2–13·5×4·5–6 μ, 8 in number, sometimes a few degenerate, irregularly uniseriate, ends overlapping, at first hyaline, then light brown, then bright deep brown (golden brown) and ultimately very dark brown, ellipsoid or ovato-ellipsoid, unequal-sided, more convex on one side, or concave on one side and convex on the other, ends rounded, more narrowed on one end than on the other, smooth, thick-walled, aguttate. *Paraphyses* 88–123×1·3–1·8 μ, up to 2·7 μ wide at the top, hyaline individually, brown in a mass, filiform, septate, simple or branched, strongly hooked at the top, also enlarged at the top. Text-Fig. 5, A–C.

Collected on dead wood (of logs) of *Quercus incana* Roxb., The Park Road, Mussoorie, August 12, 1956, **314**.

This fungus closely resembles in all respects *Bulgaria inquinans* (Pers. ex Hook.) Fr. [= *Phaeobulgaria inquinans* (Pers.) Nannf.] and a few minor differences noticed fall within the normal range of variations of the species. The paraphyses of this species are apparently hyaline at first, becoming coloured and swollen at the top in later stages. Rehm (1, 3, 1896, p. 495 in *Rab. Crypt. Fl.*) describes and illustrates them as hooked (" oft hacking gebogen ").

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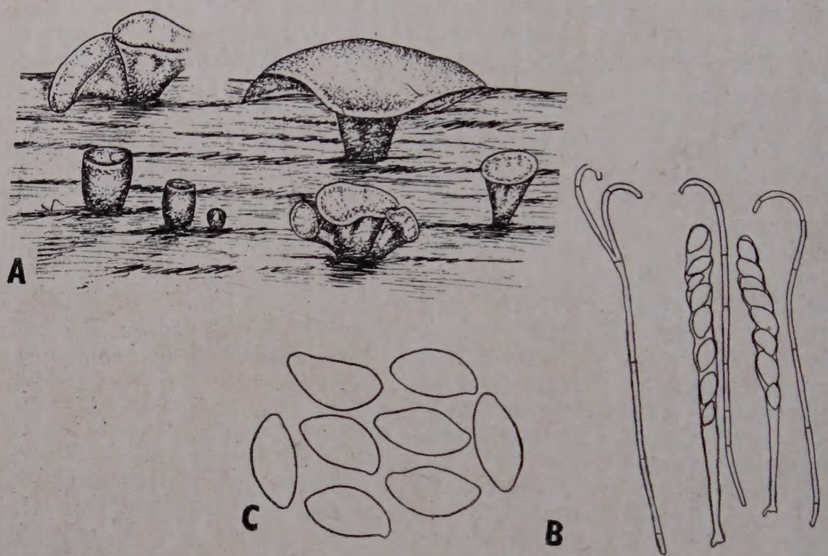
* Korf, R. P. (Nomenclatural notes II. On *Bulgaria*, *Phaeobulgaria*, and *Sarcosoma*. *Mycologia*, 1957, **49**, 102-06) has pointed out that *Bulgaria* must be used for the inoperculate species such as *B. inquinans* (Pers. ex Hook.) Fr., and not for the operculates, as had previously been the usage.



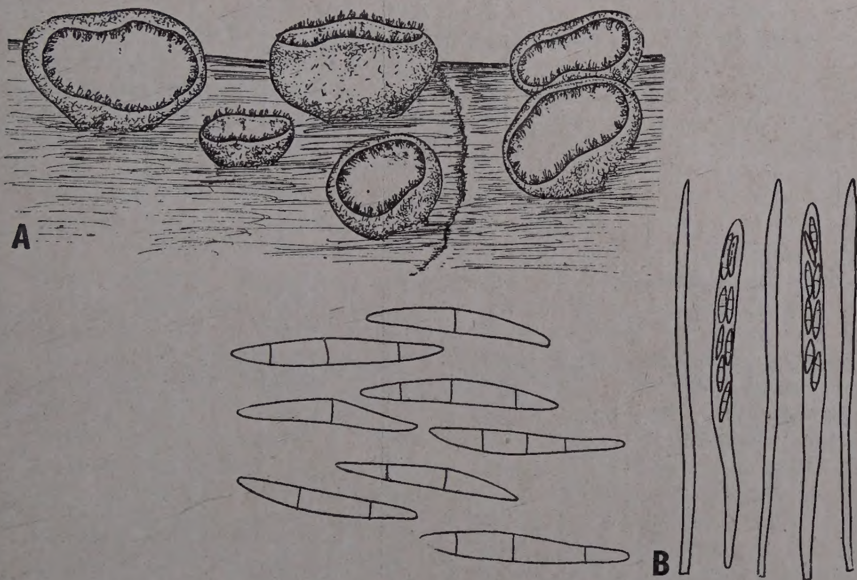
TEXT-FIG. 5. *Bulgaria inquinans* (Pers. ex Hook.) Fr. A. Apothecia, ×1. B. Asci and paraphyses strongly hooked at the top, ×400. C. Ascospores, ×950.

6. ***Dasyscyphus*** * ***sulphurea*** **(Pers. ex Fr.) Mass.,** *Brit. Fung. Flora*, **4:** 352, 1895 [= *Lachnella sulphurea* (Pers.) Quél., *Ench. Fung.*, 315, 1886].

Apothecia 0·3–1·2 mm. in diameter, gregarious to densely crowded, at first globose, then expanding and becoming shallow cupulate to discoid, regular, irregular and slightly contorted due to mutual compression, yellow (from the yellow hairs), soft and fleshy, hairy, sessile, attached at the centre only; external surface brown but appearing greyish white due to the presence of pale coloured tomentum; tomentose hairs pale yellowish brown or ochraceous brown, minute; excipular cells 5·4–16·2 μ wide, spherical to variously angled, pseudoparenchymatous, thin-walled, light brown to subhyaline individually, brown in a mass; margin entire, densely hairy, slightly elevated and slightly inturned; hairs 115–234×2·7–7·2 μ, rich yellow, in large pyramidal fascicles, simple, smooth, long and narrow, apex acute to blunt, closely septate, very slightly thick-walled, straight, highly hygroscopic turning inward and closing the hymenium in dry weather or on drying, on wetting again spreading out and opening the hymenium; hymenium whitish brown to light brown to deep brown or dark brown, even, smooth, concave to plane. *Asci* 83–98×5·4–9 μ, narrowly cylindric, apex rounded, tapering below into a stem-like base, not turning blue with iodine, inoperculate. *Ascospores* 18–27×2·2–3·7 μ, 8 in number,

* *See* foot-note under the next species.

irregularly biseriate, ends overlapping, pale yellow, slender ellipsoid, ends rounded, 1–3 septate, smooth, slightly bent or curved. *Paraphyses* 90–124×2·7–4·5 μ, lanceolate, resembling asci except the acute apices and somewhat less wide, pale ochraceous, aseptate, simple. Text-Fig. 6, A–C.



TEXT-FIG. 6. *Dasyscyphus sulphurea* (Pers. ex Fr.) Mass. A. Apothecia with densely hairy margin, ×20. B. Asci and aseptate paraphyses, ×400. C. 1–3 septate ascospores, ×950.

Collected on dead stems of *Strobilanthes* species, The Municipal Garden, Mussoorie, August 9, 1956, **315**.

This beautifully yellow coloured fungus was found growing very profusely on the dead herbaceous stems of *Strobilanthes* sp. and some other Angiospermic herbs in Mussoorie. It closely resembles *Dasyscypha sulphurea* (Pers. ex Fr.) Mass. [= *Lachnella sulphurea* (Pers.) Quel.] except for the following differences:—

	D. sulphurea	*Mussoorie fungus*
1.	Hymenium whitish or creamy white	Hymenium whitish brown to light brown to deep or dark brown
2.	Ascospores 8–10 × 1·5–2 μ, rarely 15–16 μ long	Ascospores in general 18–27 × 2·2–3·7 μ
3.	Hairs minutely roughened	Hairs smooth, filled up with coloured granules

The hairs on the apothecia of this species are said to be very slightly granulate. In the Mussoorie fungus the hairs are smooth but are filled up with coloured granules.

7. ***Dasyscyphus* subochracea*** **(Cooke *et* Peck) Comb. nov.** [= *Lachnella subochracea* (Cooke and Peck) Seaver, *North Amer. Cup-fungi* (*Inoperculates*), 251, 1951].

Apothecia 0·5–1·1 mm. in diameter and 0·57–0·9 mm. in height, singly, gregarious to densely gregarious, sometimes crowded, globose and closed when young, later on opening and becoming cupulate to shallow cupulate and finally discoid, regular, rarely contorted due to mutual compression, yellow, on drying turning whitish, fleshy and soft but fragile, hairy, stipitate; flesh lighter coloured and unchanging on exposure; taste and smell inparticular; external surface lighter coloured than the hymenium, creamy white to pale yellow, densely hairy, excipular cells not present but the excipulum is composed of agglutinated hyphae and is concolorous to external surface; hairs 108–234×2·7–3·6 μ, white to the naked eye and subhyaline under the low power of microscope, singly, dense, simple, short to long, flexuous, hypha-like, multi-septate, strongly roughened (encrusted), apex round and blunt, slightly thick-walled; margin entire, elevated, inturned, hairy, and hairs inturned and form a sort of fringe at the bottom; hymenium yellow, smooth, even, concave to plane; stipe 266–608 μ long and 114–228 μ wide, cylindric, expanding above abruptly into the apothecium, densely hairy, concolorous with the external surface, solid, fleshy, soft, but fragile, short to long. *Asci* 36–48·7× 3·7–5·2 μ, short and clavate, apex round, tapering below into a short stem-like base, not turning blue with iodine, inoperculate. *Ascospores* 6·7–8·3×1·5–2·2 μ, 8 in number, irregularly biseriate, often overlapping, hyaline, very narrowly ellipsoid or fusoid, ends narrowed, smooth multiguttulate when young, guttules small, aguttate when mature. *Paraphyses* 54·7–67×0·75–1·1 μ, hyaline, filiform, slender, simple, non-septate, not enlarged at the top. Text-Fig. 7, A–C.

Collected on dead twigs of *Rubus* specis under Oak Forest, The Cemetery, Camel's Back, Mussoorie, August 14, 1957, **316**.

This beautiful fungus is quite common in the Mussoorie Hills and grows abundantly on the dead twigs of *Rubus* species. It closely resembles *Lachnella* subochracea (Cooke and Peck) Seaver, except that its spores are somewhat shorter and its hairs are well developed and densely encrusted (roughened).

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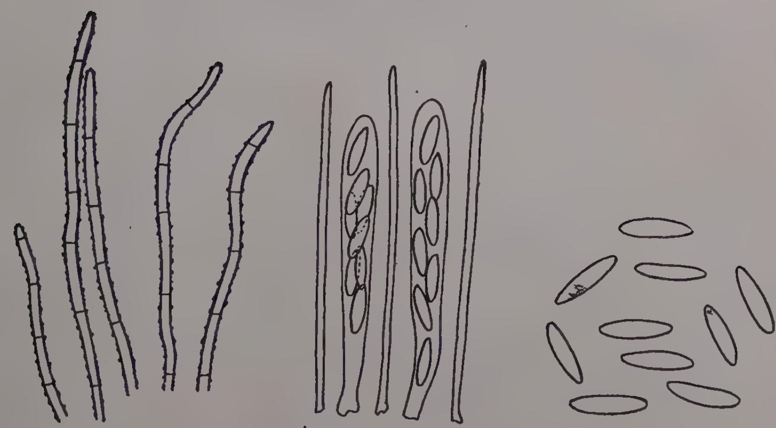
* The generic name *Lachnella* is not generally accepted by mycologists as applicable to Discomycetes, since its type is a Basidiomycete. Nannfeldt, 1932, uses *Lachnum* for most of the species which Seaver, 1951, includes in *Lachnella* while most other authors use the generic name *Dasyschyphus* or *Dasyscypha*. *Dasyscyphus* was first used by Gray, 1821, and *Dasyscypha* by Fuckel, 1870, for the names *Lachnella* and *Lachnum*. For fuller nomenclatural details of these genera *see* Dennis, 1949, and Korf, 1954.

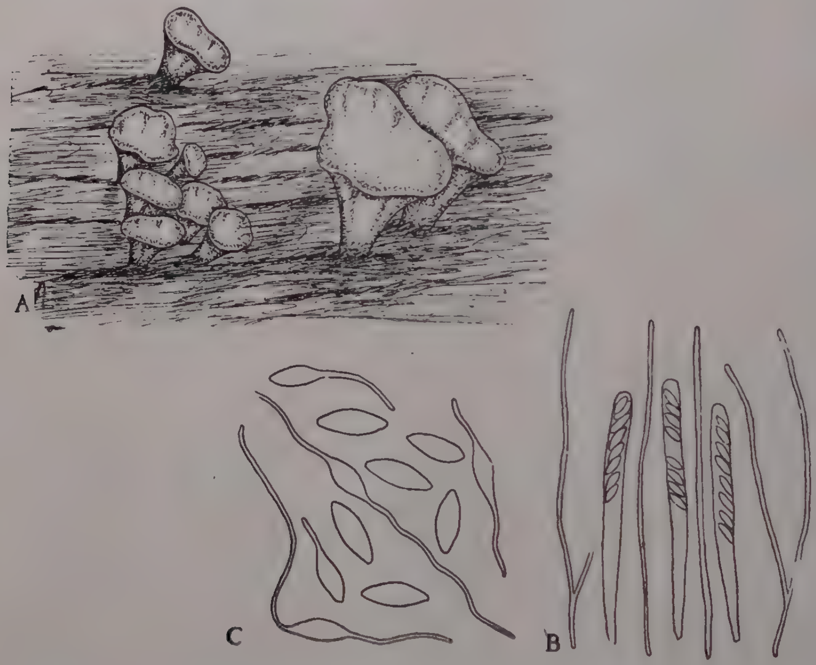


TEXT-FIG. 7. *Dasyscyphus subochracea* (Cooke & Peck) Comb. nov. A. Asci, and paraphyses, ×950. B. Ascospores, ×1150. C. Roughened hairs, ×950.

8. *Chlorociboria aeruginosa* (Oed. ex Fr.) Seaver in Ramamurthi, Korf and Batra, *Mycologia*, **49**: 859, 1957. [= *Chlorociboria aeruginosa* (Oed. ex Fr.) Seaver in *Mycologia*, **28**: 391, 1936, *nomennudum*].

Apothecia 1·5–4·5 mm. in diameter, 1–3 mm. in height, singly, densely gregarious to crowded, at first shallow cupulate, later on expanding and becoming discoid but with margin often slightly elevated, regular, often irregular and contorted due to mutual compression, greenish blue or verdigris-green, and producing a similar colour in the wood on which it grows, colour fading to whitish blue later on, soft and fleshy, smooth, stipitate; flesh concolorous and unchanging; taste and smell inparticular; external surface deep verdigris-green, much darker than the hymenial surface and does not fade, even, smooth, excipular cells 5·4–14·4 µ wide, deep greenish blue; polygonal to irregular, slightly thick-walled, pseudoparenchymatous; margin entire, slightly elevated, often wavy due to mutual compression, smooth; hymenium verdigris-green, fading to whitish blue to almost white with a few coloured specks, on drying it becomes yellowish, smooth and even, slightly concave to plane; stipe 0·5–1·5 mm. long, and 0·3–1 mm. wide, dark verdigris-green, not fading, darker than the external surface, the base is almost blackish blue, smooth, short, cylindric, expanding above into the apothecium, solid, soft and fleshy. *Asci* 61–72 × 3·6–6·3 µ, narrow cylindric to clavate, apex rounded, tapering below gradually into a stem-like base, not turning blue with iodine, inoperculate. *Ascospores* 8·2–10·5 × 2·2–3 µ, mostly 9–10 µ long, 8 in number, uniseriate, usually oblique, rarely parallel, overlapping or not, pale ochraceous, narrowly ellipsoid to fusoid, ends narrowed, smooth, aguttate, thin-walled, often found germinating inside the apothecium but not inside the ascus, germinating by 1–2 germ tubes. *Paraphyses*

74–108 × 0·3–0·9 μ, very filiform and very slender, very pale ochraceous to subhyaline, non-septate, apex not enlarged, simple or branched. Text-Fig. 8, A–C.



TEXT-FIG. 8. *Chlorociboria aeruginosa* (Oed. ex Fr) Seaver. A. Apothecia ×5. B. Asci and paraphyses, ×400. C. Ascospores (with some germinating), ×950.

Collected on dead wood and stumps of Oak trees under Oak Forest, The Park, Mussoorie, August 11, 1956, **317**. On dead wood and stumps of Oak trees under Oak Forest, Bilaru Khad, Mussoorie, August 25, 1957, **318**.

This very interesting fungus is quite common in the Mussoorie Hills and is always found on dead wood. It is characteristically verdigris-green. The colour is not only superficial but the interior of the apothecium also shows colouration. Thus, when examined in a vertical section, the epithecium is deep greenish blue to whitish, the hymenial layer light green blue to whitish, hypothecia (or subhymenial layer) greenish blue, and the context is composed of thick-walled highly convoluted hyphae which are hyaline to subhyaline individually but with a faint greenish blue tinge in a mass, while the excipular layer is thick-walled, pseudoparenchymatous and deep greenish blue. The stipe is always present and is deeper coloured. The paraphyses are exceedingly filiform and are not enlarged above. The spores are seen abundantly germinating in the apothecium.

This fungus belongs to *Chlorociboria aeruginosa* (Oed.) Seaver, but differs from the latter in some minor respects:—

	C. aeruginosa	*Mussoorie fungus*
1.	Asci 45–50 × 3–4 μ	Asci 61–72 × 3·6–6·3 μ
2.	Spores 2-seriate	Spores uniseriate and usually oblique
3.	Spores also irregularly crowded	Never irregularly crowded
4.	Spores 2–2·5 × 5–7 μ, rarely 10–12 μ long	Spores 8·2–10·5 × 2·3–3 μ mostly 9–9·7 μ
5.	Paraphyses 1·5 μ wide	Paraphyses 0·3–0·9 μ, wide

Acknowledgements

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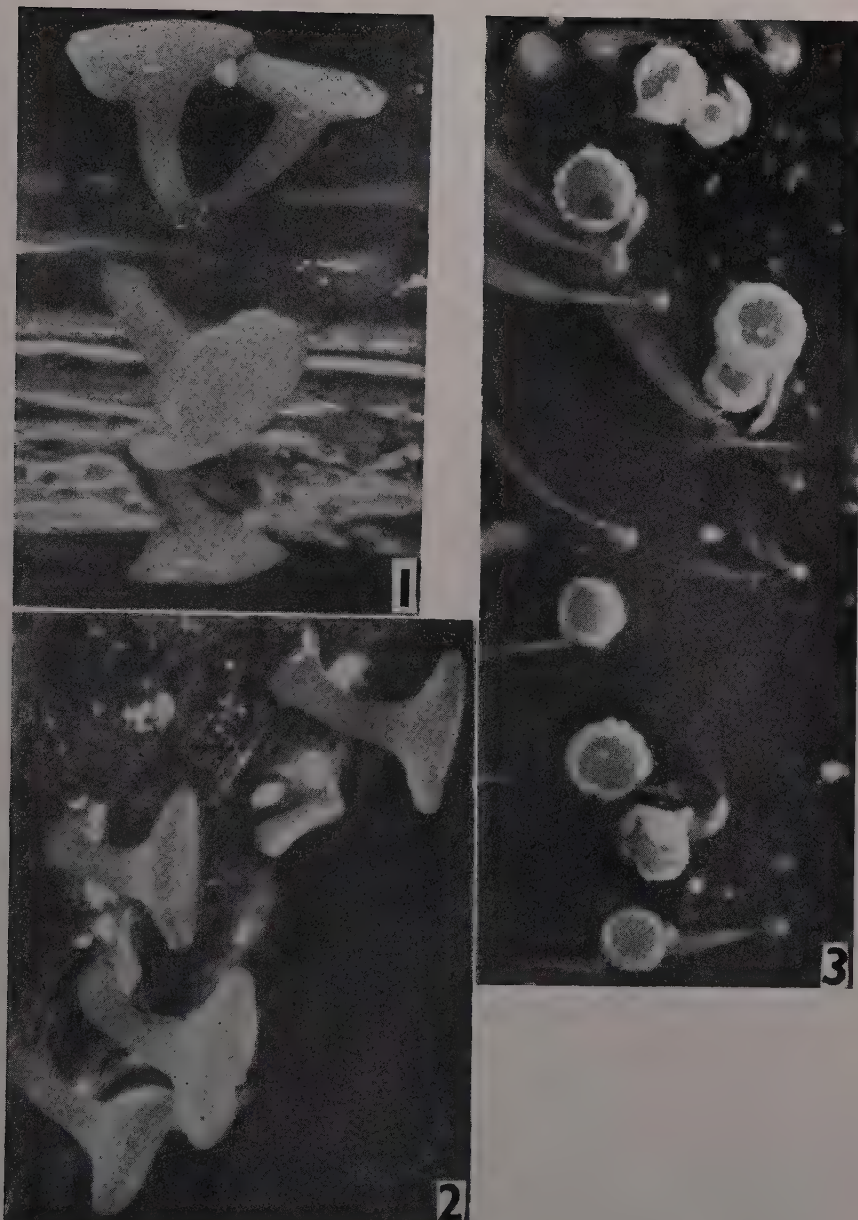
Explanation of Plate IX

Fig. 1. *Helotium scutula* (Pers. ex Fr.) Karst.

Fig. 2. *Helotium fructigenum* (Bull. ex Fr.) Fuckel.

Fig. 3. *Dasyscyphus subochracea* (Cooke *et* Peck) comb. nov.



FIGS. 1–3

K. S. Thind and Pritham Singh

INTERRELATIONS AMONGST DIFFERENT SAL FORESTS OF MADHYA PRADESH

BY N. K. JAIN

*Department of Botany, Government Degree College, Guna**

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INTRODUCTION

SAL (*Shorea robusta* Gaertn.f.) is a semi-evergreen valuable timber tree of India. In Madhya Pradesh it is distributed in the eastern parts of the State in two belts separated by Chhattisgarh plain.

Detailed phytosociological characters of Sal forests in this State have already been described by the author (1958) elsewhere. The present paper aims to determine the interrelations amongst different Sal forests of the State as also the probable trends in succession in them. However, it is to be noted that most of the Sal forests of Madhya Pradesh are coppice growths.

Different views have been expressed on the status of Sal forests in general. Chakravarti (1948) labels dry Peninsular Sal as edaphic or biotic subclimax. Puri (1950) believes that Sal forests of Dehra Dun are tenable due to bio-edaphic seral association preserved by human interference. According to Misra and Puri (1957) the entire forests of India may be classed to belong to " bio-edaphic " series of succession. Hewetson (1955) ascribed Sal to have attained climatic climax in Madhya Pradesh (Central India) where it constitutes 90% of total crop with *Terminalia tomentosa*.

However, the course of succession from poor to good Sal forests has not yet been indicated. The study on the probable trends in succession in the forests from poor to good growth is helpful in evaluating the exact status of the species and consequently means can be provided to maintain it with advantage.

METHODS

For a better understanding of the growth behaviour of Sal the average height of the trees of a locality has been taken as an index of the quality of Sal crop there. No standard method was employed for the determination of the height of Sal trees and has only been noted by spot enquiry and visual aid. Thus Sal forests of M.P. have been artificially grouped into the following height classes for convenience:—

* The work was conducted at the Department of Botany, Mahakoshal Mahavidyalaya, Jabalpur.

Average height of the tree 90 feet or more .. Class I
Average height of the tree between 70 to 89 feet .. Class II
Average height of the tree between 50 to 69 feet .. Class III
Average height of the tree below 50 feet .. Class IV

Phytosociological characters were noted as per methods given by the author (1958). In ranking the various species under succession the method of cover × frequency coefficient as adopted by Pandeya (1952) after Dyksterhuis (1946) has been used. This method is found useful by them in ranking some species where coverage alone appears inadequate to express its relative importance over the area as a whole. Relative importance is calculated by the following formula:—

$$\text{Relative importance} = \frac{\%\ \text{cover} \times \%\ \text{frequency}}{100}$$

The following Sal forests belonging to the various height classes have been examined:—

Height-class	Forests	Range	Division
I. (*a*)	Kharka and donga tola	Nagri	South Raipur
(*b*)	Kharka	Risgaon	South Raipur
(*c*)	Tiria forests (Tigri Pagar and Machkot)	East Jagdalpur	East Bastar
II. (*a*)	Forests on way to Gorila from Mukie village	Mukie	Balaghat
(*b*)	Forests on way to Kanha from Kisli	Banjar	Mandla
(*c*)	Biramgaon forest	Risgaon	South Raipur
(*d*)	Forests near Dhanpunji village	East Jagdalpur	East Bastar
III. (*a*)	Forests on way to Kapil dhara	Amarkantak	Rewa
(*b*)	Sitapur forests	Shahdole	Rewa
(*c*)	Forests on the bank of Maniari canal near Kari dongri village	Lormi	Bilaspur

Height-class	Forests	Range	Division
	(*d*) Forests on way to Chhota Mahadeva and Big Fall	Pachmari	Hoshangabad
	(*e*) Circular road	Risgaon	South Raipur
	(*f*) Forest near the village Dhanpunji	East Jagdalpur	East Bastar
IV.	(*a*) Forests between Amarkantak and Pendra	Amarkantak	Rewa
	(*b*) Forests behind Kisli Rest House	Banjar	Mandla
	(*c*) Forests on way to Chhota Nala, Bee Fall and Dhoopgarh	Pachmari	Hoshangabad
	(*d*) Forests on way to Gorila from Mukie village	Mukie	Balaghat
Sal Biotic (Community)			
	(*a*) Forest near Aamer and Kulai Chunda near Bikrampur	Dindori	Mandla
	(*b*) Forest between Baikuntpur and Nagar	Baikuntpur	Koria

Aamer, Bikrampur and Baikuntpur forests are under moderate to heavy biotic interference; thus they are grouped separately as Sal biotic community. This has been done to distinguish them from other reserve Sal forests and to know the affect of biotic operation on Sal.

Authorities for naming the species have been given in Table II.

Results

The average values of quantitative characters of different height class forests are presented in Table I. It is interesting to note that adult Sal trees tend to be sparsely distributed as the growth of Sal becomes better. Thus, in height-class I average abundance per quadrat is 2·36, in class II 4·72, in class III 5·06 and in class IV 4·50. Conversely the percentage cover per plant of Sal decreases with height classes. Thus, percentage cover per tree from height-class I to IV is 38·3, 14·63, 13·2, and 11·3, respectively.

2

TABLE I

Quantitative characters of Sal forests belonging to different height-classes and biotic communities (average values)

No.	Species	Sal height-class I			Sal height-class II			Sal height-class III			Sal height class IV			Sal biotic community		
		A	F	C	A	F	C	A	F	C	A	F	C	A	F	C
1	*Shorea robusta* ..	2·36 (0·45±)	100	90·40	4·72 (5·80±)	100	69·00	5·06 (3·20±)	100	66·00	4·45 (2·14±)	100	50·00	2·70 (4·30±)	100	55·70
2	*Terminalia tomentosa*	0·18	18	4·00	0·18	27	3·00	0·50	26	6·30	0·50	43	6·78	0·14	14	0·71
3	*Syzygium cumini*	0·36	36	7·00	..	..	..	0·06	7	0·60	0·14	14	4·90	..	..	..
4	*Anogeissus latifolia*	0·18	18	2·00	0·18	18	1·33	0·13	20	3·30	0·51	35	6·70	0·14	14	4·30
5	*Semecarpus anacardium*	0·09	9	2·00	..	..	..	..	..	..	..	..	..	..	..	..
6	*Buchanania lanzan*	0·09	9	1·00	0·10 (0·10±)	18	0·90	0·13	7	1·60	0·23	35	4·20	0·57	28	4·30
7	*Diospyros melanoxylon*	0·18	18	2·00	0·70 (0·70±)	27	2·85	0·06	14	0·25	..	..	..	0·71	14	0·06
8	*Clausena pentaphylla*	0·18	18	1·00	..	..	.	..	..	..	..	..	..	..	..	..
9	*Cassia fistula* ..	0·09	9	0·45	..	..	..	0·06	7	0·33	..	..	..	..	..	..
10	*Adina cordifolia* ..	0·18	18	2·00	..	..	..	..	..	..	..	..	..	..	..	..
11	*Acacia catachu* ..	0·09	9	0·45	..	..	..	..	..	..	..	..	..	..	..	..
12	*Mallotus philippinensis*	0·18	18	3·00	..	..	..	0·06	7	1·32	..	..	..	..	..	..
13	*Lannea coromandelica*	0·09	9	0·18	..	..	..	..	..	..	..	..	..	0·14	14	2·80
14	*Embliea officinalis*	..	..	..	0·10	9	0·18	..	..	..	..	..	..	0·14	14	2·80
15	*Madhuca indica* ..	..	..	..	0·27	27	2·36	0·40	26	1·27	0·07	14	1·42	..	..	..

16	*Careya arborea* ..	..	..	..	0·14	9	0·14	..	..	..	0·07	7	0·71	..	..	..
17	*Bauhinia variegata*	..	..	..	0·10	9	0·28	..	..	..	..	..	..	..	..	..
18	*Bauhinia racemosa*	..	..	..	0·10	9	0·18	0·13	7	1·30	..	..	..	0·43	14	5·70
19	*Albizzia odoratissima*	..	..	..	0·10	9	0·09	..	..	..	..	..	..	..	..	..
20	*Cleistanthus collinus*	..	..	..	..	..	..	0·18	20	2·56	..	..	..	..	..	..
21	*Terminalia belerica*	..	..	..	..	..	..	0·12	7	2·00	0·07	7	0·36	..	..	..
22	*Pterocarpus marsupium*	..	..	..	..	..	..	0·06	7	2·00	0·07	14	0·14	0·14	14	5·70
23	*Boswellia serrata*	..	..	..	..	..	..	..	..	..	0·35	28	5·70	..	..	..
24	*Butea monosperma*	..	..	..	..	..	..	..	..	..	0·07	7	0·71	0·40	14	7·00
25	*Saccopetalum tomentosum*	..	..	..	..	..	..	..	..	..	0·07	7	0·36	..	..	..
26	*Dendrocalamus strictus*	..	..	..	..	..	..	..	..	..	0·21	14	0·85	..	..	..
27	*Bauhinia vahlii* ..	..	..	..	..	..	..	..	..	..	..	..	..	(0·75 ±)	14	..
28	*Ficus religiosa* ..	..	..	..	..	..	..	..	..	..	..	..	..	0·14	14	4·30
29	*Albizzia procera* ..	..	..	..	(0·09 ±)	9	..	..	..	..	..	..	..	..	..	..
30	*Phoenix sylvestris*	..	..	..	(2·40 ±)	36	..	..	..	..	..	..	..	..	..	..
31	*Phoenix acaulis* ..	..	..	..	(1·80 ±)	36	..	..	..	..	..	..	..	..	..	..
32	*Ficus variegata* ..	0·09	9	1·00	..	..	..	..	..	..	..	..	..	..	..	..
33	*Miliusa velutina*	..	..	..	..	..	..	0·06	7	1·32	..	..	..	..	..	..
34	*Desmos longiflorus*	..	..	..	..	..	..	0·06	7	2·00	..	..	..	..	..	..

Note.—(i) A—Abundance; F—Frequency %; C—Cover %.
(ii) ±: Figures within brackets are number of saplings.

Table II shows synthetic character 'constance' of Sal associates including the other species which are occasionally present but not recorded in the quadrats. In all 69 other species have been observed

TABLE II

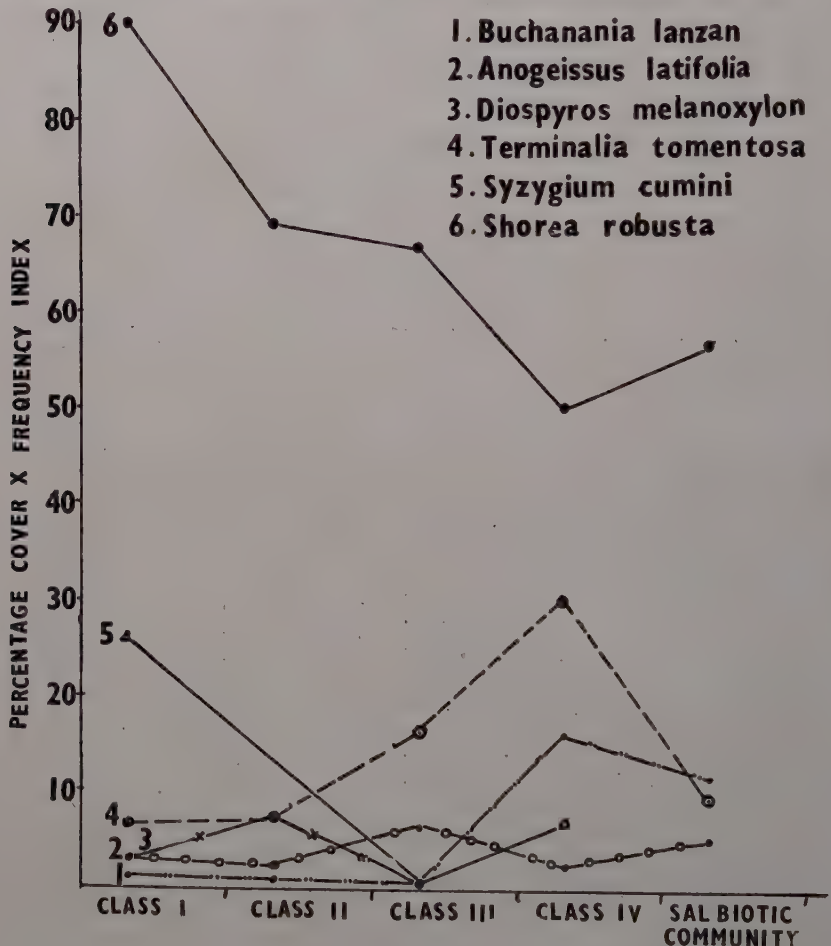
Constancy values of all the species of Sal association in forests belonging to different height-classes and biotic community

No.	Species	Sal height-classes				Sal biotic community
		I	II	III	IV	
1.	*Shorea robusta* Gaertn. f. ..	5	5	5	5	5
2.	*Terminalia tomentosa* W. & A.	1	1	2	3	1
3.	*Syzygium cumini* (Linn.) Skeels.	2	0	1	1	0
4.	*Anogeissus latifolia* Wall. ..	1	1	1	2	1
5.	*Semecarpus anacardium* Linn. ..	1	0	0	1	0
6.	*Buchanania lanzan* Spreng. ..	1	1	1	2	2
7.	*Diospyros melanoxylon* Roxb. ..	1	1	1	1	1
8.	*Clausena pentaphylla* DC. ..	1	0	0	1	0
9.	*Cassia fistula* Linn. ..	1	1	1	1	0
10.	*Adina cordifolia* HK. f. ..	1	0	0	1	0
11.	*Acacia catachu* Wild. ..	1	0	1	0	0
12.	*Mallotus philippinensis* Muell. ..	1	0	1	0	0
13.	*Lannea coromandelica* (Houtt.) Merr.	1	0	1	1	1
14.	*Emblica officinalis* Gaertn. ..	0	1	0	1	1
15.	*Madhuca indica* Gmel. ..	1	2	2	1	0
16.	*Careya arborea* Roxb. ..	0	1	0	1	0
17.	*Bauhinia variegata* Linn. ..	0	1	0	1	0
18.	*Phoenix sylvestris* (Linn.) Roxb.	0	1	0	1	0
19.	*Phoenix acaulis* Buch. Ham. ..	0	1	0	1	0
20.	*Albizzia procera* Benth. ..	0	1	1	1	0
21.	*Bauhinia racemosa* Lamk. ..	0	1	1	0	0
22.	*Albizzia odoratissima* Benth. ..	0	1	0	1	0
23.	*Cleistanthus collinus* Benth. ..	0	0	1	1	0
24.	*Terminalia balerica* Roxb. ..	0	1	1	1	1
25.	*Pterocarpus marsupium* Roxb.	1	1	1	1	1
26.	*Boswellia serrata* Roxb. ..	0	0	0	2	0
27.	*Butea monosperma* (Lamk.) Kuntze	0	0	0	1	1
28.	*Saccopetalum tomentosum* HK. f. & T.	0	0	0	1	0
29.	*Dendrocalamus strictus* Nees.	0	0	0	1	0
30.	*Bauhinia vahlii* W. & A. ..	0	0	0	1	1
31.	*Ficus religiosa* Linn. ..	0	0	0	1	1
32.	*Ficus hispida* L. f. ..	1	0	0	1	0

Table II (*Contd.*)

No.	Species	Sal height-classes I	II	III	IV	Sal biotic community
33.	*Miliusa velutina* Hook. f. & Th.	0	0	1	0	0
34.	*Desmos longiflorus* (Roxb.) Sefford	0	0	1	0	0
35.	*Terminalia chebula* Retz. ..	0	1	1	1	1
36.	*Lagerstroemia parviflora* Roxb.	0	0	1	1	0
37.	*Dalbergia paniculata* Roxb. ..	0	1	1	1	0
38.	*Mitragyna parvifolia* (Roxb.) Korth	1	0	1	1	0
39.	*Salmalia malabarica* (DC.) Schott. & Endl.	1	1	1	1	0
40.	*Nyctanthus arbor-tristis* Linn. ..	0	0	0	1	1
41.	*Terminalia glabra* W. & A. ..	1	1	1	1	0
42.	*Woodfordia fruticosa* (Linn.) Kurz.	0	0	1	1	0
43.	*Casearia graveolens* Dalz. ..	0	0	1	1	0
44.	*Grewia hirsuta* Wahl. ..	0	1	1	1	0
45.	*Schrebera swietenioides* Roxb.	0	1	1	1	0
46.	*Ougenia oojeinensis* (Roxb.) Hochreut	0	0	1	1	0
47.	*Zizyphus xylopyrus* Wild. ..	0	0	1	1	0
48.	*Cedrela toona* Roxb. ..	0	0	1	1	0
49.	*Bauhinia malabarica* Roxb. ..	0	0	1	1	1
50.	*Bridelia retusa* Spreng. ..	0	0	1	1	0
51.	*Kydia calycina* Roxb. ..	0	0	1	1	0
52.	*Gmelina arborea* Roxb. ..	0	1	1	1	0
53.	*Hymenodictyon excelsum* Wall.	1	1	1	0	0
54.	*Garuga pinnata* Roxb. ..	0	0	1	1	0
55.	*Grewia tilaefolia* Vehl. ..	0	0	0	1	1
56.	*Elaeodendron glaucum* Pers. ..	0	1	1	1	0
57.	*Symplocos racemosa* Roxb. ..	0	0	0	1	0
58.	*Strychnos potatorum* Linn. ..	0	0	1	1	0
59.	*Gardenia resinifera* Roth. ..	0	0	1	1	0
60.	*Dillenia pentagyna* Roxb. ..	2	1	1	0	1
61.	*Croton oblongifolius* Benth. ..	0	0	0	1	1
62.	*Randia spinosa* BL. ..	0	0	0	1	1
63.	*Protium serratum* (Wall. ex. Colebr.) Engl.	1	1	0	0	0
64.	*Holarrhena antidysenterica* Wall.	0	0	1	1	1
65.	*Anthocephalus cadamba* Mig. ..	0	0	1	0	1
66.	*Antidesma ghaesembilla* Gaertn.	0	1	0	1	0
67.	*Flacourtia indica* (Burm. f.) Merr.	0	0	1	1	1
68.	*Randia uliginosa* DC. ..	0	0	0	1	0
69.	*Ficus glomerata* Roxb. ..	0	0	0	0	1
70.	*Erythrina variegata* Linn. ..	0	0	0	1	1

to grow with Sal in different proportions in the forests. It is evident from Table II that Sal is exclusively dominant having constance value 5 in all the examined forests. Relative importance of some dominant species of Sal forests have been given in Text-Fig. 1.



TEXT-FIG. 1

INTERPRETATION AND DISCUSSION

The foregoing observations may be discussed under the following heads:—

1. Structural differences among the various height-class forests.
2. Selectivity or constance of different species,

3. Successional trends in the forests having poor to good growth of Sal.

1. *Structural Differences among the Various Height-Class Forests*

The structural differences in the various height-class forests may be largely due to density of Sal population. The average figures of abundance and cover have already shown that as Sal crop tends to grow better, the individual tree occupies more of the area and consequently is hypodispersed.

The species next in importance to Sal in height-class I, with respect to percentage frequency and cover is *Syzygium cumini* (frequency 36%, cover 7%). The other species having 18% frequency are *Terminalia tomentosa* (cover 4%), *Anogeissus latifolia* (cover 2%), *Diospyros melanoxylon* (cover 2%), *Adina cordifolia* (cover 2%) and *Clausena pentaphylla* (cover 1%). Rest of the species have only less than 10% frequency and less than 1% cover. Keeping this in view and following the association concept as given by Pandeya (1953) for grassland, the height-class I forests may be tentatively called as *Shorea-Syzygium* type.

In height-class II Sal forests, three species have been observed with 27% frequency although their cover percentage is low. *Terminalia tomentosa* has 3% cover, *Diospyros melanoxylon* has 2·8% cover and *Madhuca indica* has 2·36% cover. Although *Diospyros melanoxylon* is very close to *Terminalia tomentosa*, yet the latter has been found to have slightly more cover than the former, the height-class II Sal forests may be grouped as *Shorea-Terminalia* type. The other species of this class having 18% frequency are *Anogeissus latifolia* (cover 1·33%), *Buchanania lanzan* (cover 0·9%) and *Cassia fistula* (cover under growth). Remaining species have less than 10% frequency.

Next to Sal in height-class III forests, are *Terminalia tomentosa* (cover 3·6%) and *Madhuca indica* (cover 2·7%) having 26% frequency, whereas *Anogeissus latifolia* (cover 3·3%) and *Cleistanthus collinus* (cover 5·6%) have 20% frequency. *Diospyros melanoxylon* here shows only 14% of frequency and 0·2% of cover. Remaining species have less than 10% frequency. On the basis of frequency and cover, Sal height-class III forests may be called *Shorea-Terminalia-Madhuca* type.

Many species are co-dominant in height-class IV forests. Here *Terminalia tomentosa* has 43% frequency and 6·7% cover. *Anogeissus latifolia* and *Buchanania lanzan* (cover 4·2%) have 35% frequency. Species having 14% frequency are *Syzygium cumini* (cover 4·9%), *Madhuca indica* (cover 1·2%), *Pterocarpus marsupium* and *Dendrocalamus strictus*. Rest of the species have less than 10% frequency. In this type of forests interestingly co-dominants are more and consequently Sal has only 50% cover which is the least amongst the examined forests. These forests may be labelled as *Shorea-Terminalia-Anogeissus-Buchanania* type.

Referring to the biotic community of Sal it is noted that Sal has low percentage cover and low abundance value. The low abundance may indicate that it had attained good growth in the past. The present

status of this community may be due to biotic influence. The anthropogenic factors can directly influence percentage cover by introducing or eliminating few other species. In these forests *Buchanania lanzan* becomes second important species having 28% frequency and 4·3% cover. Curious enough, all other species of the forests have 14% frequency. It may be concluded that Sal biotic community may be classed *Shorea-Buchanania* type, with all other species having almost equal importance. This community comparatively has less number of species than the preceding height-class forests.

2. *Selectivity or Constance of Different Species*

It is evident from Table II that no species is absolutely exclusive to any of the Sal height-class forests. However, some species do occur with increasing or decreasing proportion or may be completely absent from one or more height-class forests. Based on the constance, total species occurring in all the forest types may be divided into the following categories:—

(1) Species with increasing order from height-class I to IV.

(2) Species with decreasing order from height-class I to IV.

(3) Species uniformly distributed throughout.

(4) Species present in the height-class III and IV only.

(5) Indifferent species.

The species belonging to the above different groups are as follows:—

1. *Terminalia tomentosa*, *Anogeissus latifolia*, and *Buchanania lanzan*.

2. *Syzygium cumini and Madhuca indica.*

3. *Diospyros melanoxylon*, *Hymenodictyolon excelsum*, *Cassia fistula*, *Salmalia malabarica*, *Pterocarpus marsupium* and *Terminalia glabra*.

4. *Boswellia serrata*, *Butea monosperma*, *Saccopetalum tomentosum*, *Dendrocalamus strictus*, *Casearia graveolens*, *Ougenia oojeinensis*, *Zizyphus xylopyrus*, *Cedrela toona*, *Bauhinia malabarica*, *Bridelia retusa*, *Kydia calycina*, *Symplocos racemosa*, *Strychnos potatorum*, *Gardenia resinifera*, *Dillenia pentagyna*, *Holarrhena antidysenterica*, *Flacourtia indica*, *Randia spinosa*, *Grewia hirsuta*, *Woodfordia fruticosa*, *Lagerstroemia parviflora*, *Nyctanthus arbortristis*, *Cleistanthus collinus*, *Miliusa velutina* and *Desmos longiflorus*.

5. Remaining species belong to this group. They do not show any systematic distribution and are present in more than one height-class and do not appear to have any affinity with better or poor quality of Sal.

From the above classification *Syzygium cumini* and *Madhuca indica* appear closer to Sal since they increase with better Sal growth.

Prominent species like *Terminalia tomentosa*, *Anogeissus latifolia* and *Buchanania lanzan* appear to thrive better in poor quality of Sal, whereas *Diospyros melanoxylon* does not show any selectivity amongst different height-class forests.

3. *Successional Trends in Forests having Poor to Good Growth of Sal*

Primary succession leading to the formation of Sal forests may be traced either from miscellaneous or Teak forests or Sal may itself be a pioneer tree species. Teak giving place to Sal does not appear to be suitable proposition, since, Bhatia (1954) has shown that Teak grows in soils quite opposite to Sal habitat. Sal, therefore, has probably emerged either from miscellaneous forests or Sal as a pioneer tree species. At Pachmari forests, on way to Amarkantak from Pendra road, on way to Mukie from Baiher and on the adjoining river banks and many other places in this State Sal has been found to grow in thin coarse soils with rocks exposed here and there (generally on the top of hills). On river banks Sal has been observed to grow on coarse sand.

On the other hand, at several other places Sal forests have been found to merge into miscellaneous ones.

Thus both the above-described propositions may hold good for the invasion of this species.

With these assumptions the following two sequences in succession may be visualised:—

(*A*) *From miscellaneous forests.*—(i) Miscellaneous forests may lead to the formation of forests in which Sal may co-dominate. As per Text-Fig. 1, next important species having decreasing cover × frequency index are *Terminalia tomentosa* (Relative importance 2·35), *Buchanania lanzan* (Rel. imp. 1·47), *Anogeissus latifolia* (Rel. imp. 2·35) and *Diospyros melanoxylon*.

(ii) With the bettering of Sal growth some species decrease in their relative importance whereas others increase. Thus, *Terminalia tomentosa* (Rel. imp. 1·64), *Anogeissus latifolia* (Rel. imp. 0·66) and *Buchanania lanzan* (Rel. imp. 0·112) sharply decline whereas *Madhuca indica* (Rel. imp. 0·2 to 0·33) and *Syzygium cumini* increase from height-class IV to III.

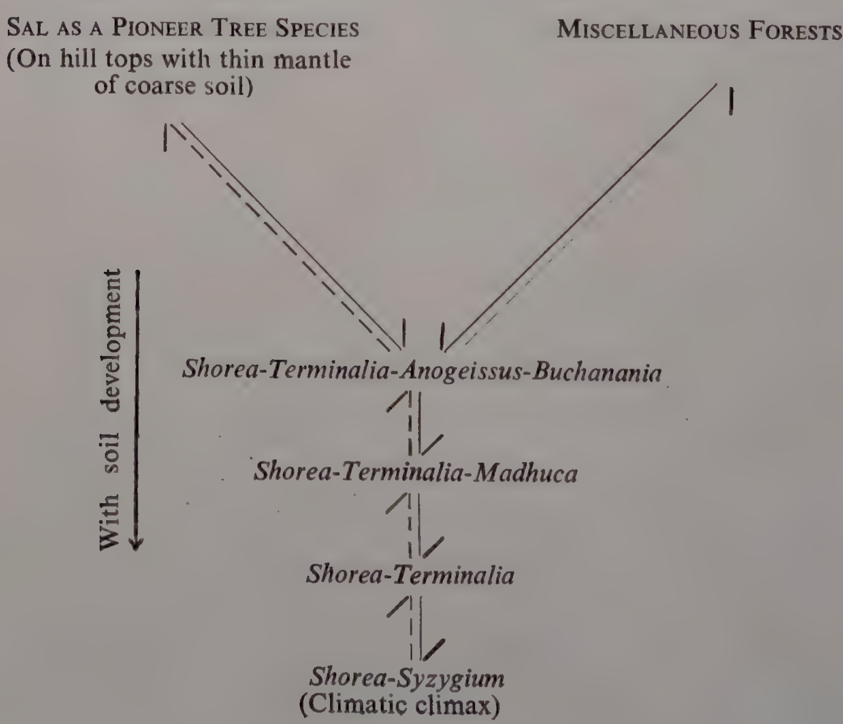
(iii) In height-class II, *Terminalia tomentosa* (Rel. imp. 0·81) and *Anogeissus latifolia* (Rel. imp. 0·24) further decrease in their cover × frequency index and *Buchanania lanzan* (Rel. imp. 0·61), *Madhuca indica* (Rel. imp. 0·64) and *Syzygium cumini* show an increase.

(iv) Finally in the height-class I, *Syzygium cumini* becomes second important species (Rel. imp. 2·62) followed by *Terminalia tomentosa* (Rel. imp. 0·72). It may be observed that *Diospyros melanoxylon*

does not show any marked fluctuation in the various height-class Sal forests and may be treated as constant species without profound affinity to any of them.

(*B*) *Sal as a pioneer tree species.*—As noted earlier there are many places around the examined forests where Sal grows on bare rocks with a very thin mantle of coarse soil. At such places generally crooked trees are situated at a distance of 20 to 25 feet from each other. This situation was observed on the top of hills. While describing the flora of the Central and Southern tracts of Bihar and Orissa, Haines (1925) writes: "The Sal itself, the most characteristic tree of the area, is somewhat xerophytic in structure. Its leaves are very nearly persistent, and they thus have to stand the dry winds of February and March, while the new ones appear in May, when the relative humidity of the area is very low.... On the gnarled with relatively massive stem and smaller leaves (the so-called hill-type Sal), but provided the drainage is sufficient, the Sal is found on fairly heavy as well as light soil." It is evident, therefore, that Sal possess the capacity to invade even the drier hill tops. Here it becomes the pioneer tree species. On the lower situations the soil is th:cker under height-class IV Sal forests. Thus further succession would have followed the same sequence as described in the miscellaneous forests.

The trends in succession in Sal forests may be diagrammatically represented as follows:—



Referring to the successional status of Sal, at least, in this State the present author is of the opinion that it forms the climatic climax. It is probably such a peculiar monastic species that it invades bare area and attains the climatic climax there. Thus the question of its being edaphic climax does not arise. Further the study has revealed that biotic operations result in poor growth of Sal. Therefore it may not even be the biotic climax species.

Summary

The paper deals with the interrelations amongst different Sal forests of Madhya Pradesh. The forests have been artificially grouped into four height-classes and a Sal biotic community. Interrelations have been established amongst these forests on phytosociological basis. The average figures of abundance and cover have shown that as Sal crop tends to better, the individual tree occupies more of the area and are thus hypodispersed. Sal has been found to be exclusively dominant in all the Sal height-class forests.

Primary succession leading to the formation of Sal forests may be traced either from miscellaneous forests or Sal may itself be a pioneer tree species. On the basis of cover × frequency coefficient, relative importance of Sal association in the forests has been determined. With the bettering of Sal growth *Terminalia tomentosa*, *Anogeissus latifolia* and *Buchanania lanzan* sharply decline whereas the proportion of *Syzygium cumini* and *Madhuca indica* show an increase. Probable course of succession from poor to good growth of the forests have been noted. Sal is probably a climatic climax of the area.

Acknowledgements

The author is deeply indebted to Dr. S. C. Pandeya, Head of the Department of Botany, Science College, Raipur, for the valuable guidance and constant encouragement throughout the period of the present investigations. Thanks are also due to the Principal, Mahakoshal Mahavidyalaya, Jabalpur, for providing necessary facilities.

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LACELLINOPSIS DESMOSTACHYAE SP. NOV.

By R. Y. Roy and R. S. Dwivedi
Botany Department, Banaras Hindu University

(Received for publication on August 21, 1959)

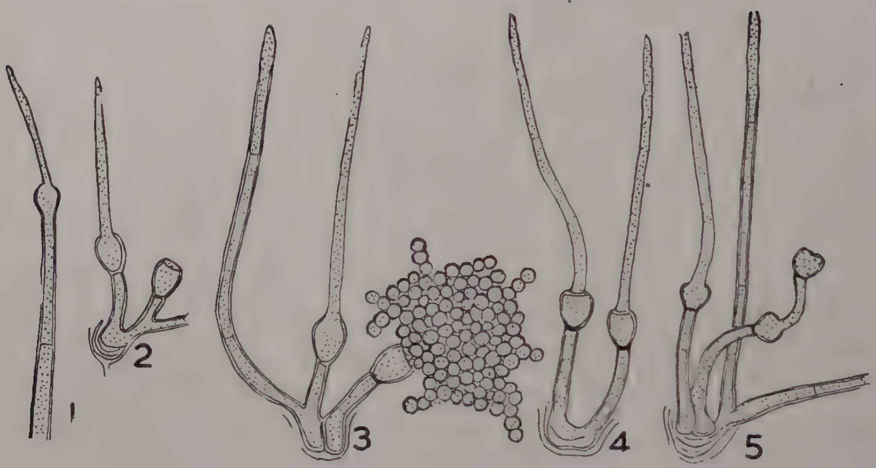
During the field observations made at a grassland in Banaras, a species of *Lacellinopsis* was found growing on dead leaves of *Desmostachya bipinnata* Stapf. It forms brown to deep brown colonies on the leaves, consisting of conidiophores and sterile setae interspersed and aggregated together. The hyphae are septate and brown in colour. The setae are unbranched, thick-walled, dark brown at the base, becoming light brown towards the apex. They commonly proliferate into sterile ones through cupulate apices. Conidiophores are simple, unbranched or sometimes branched, short, light brown to brown, with a brown globose tip. Conidiophore proliferates through cupulate apex into secondary conidiophore or into sterile seta. Conidia are catenate, single celled, globose to sub-globose, verrucose, light brown to brown.

From the above description it is evident that this fungus differs markedly from the species described by Subramanian (1953 and 1954) in proliferation of sterile setae into sterile ones, proliferation of conidiophores into secondary conidiophores or into sterile setae and the occurrence of branched conidiophores. Therefore a new species *L. desmostachyae* is being proposed.

***Lacellinopsis desmostachyae* sp. nov.**

Coloniae luteo-brunneae vel brunneolae, amphigenae; hyphae septatae, pallide brunneae; setae steriles atque conidiophori emergentes lateralitere cellulis hypharum, interspersi atque simul aggregati; setae simplices, haud ramosae, crassis parietibus praeditae, longae, subulatae, fuscae vel fuscobrunneae, crassis parietibus praeditae ad basin, pallidiores evadentes ad apicem, hyalinae in apice, usque 22-septatae, $216–450 \times 5 \cdot 4–9\,\mu$. Nonnumquam apex cupulatus evadit, per quem setae proliferant in setae steriles. Conidiophori simplices, haud ramosi, breves, ut plurimum semel vel bis septati, pallidi colore, apice globoso fusce brunneo fertili, $18–54 \times 3 \cdot 6–5 \cdot 4\,\mu$; apex fertilis $7 \cdot 2–9\,\mu$. Conidia capitata, producta acropetale ex apice globoso conidiophororum, semel cellulata, globosa, minute verruculosa, pallide vel fusce brunnea, $5 \cdot 4–9\,\mu$ diam. Capitulum globosum conidiophori cupulatum evadit post liberationem conidiorum. Conidiophori proliferant per apicem cupulatum in conidiophoros vel in setas steriles.

Typus lectus in foliis emortuis *Desmostachyae bipinnatae* in hortu botanico universitatis banarensis, ad Varanasi, mense januario anni 1958 a R.S. Dwivedi.



TEXT-FIGS. 1–5. *Lacellinopsis desmostachyae* sp. nov. Fig. 1. Proliferation of sterile seta into sterile one. Fig. 2. Proliferation of conidiophore into sterile seta. Fig. 3. Conidiophores, one with conidial head and the other proliferating into sterile seta. Fig. 4. Proliferation of conidiophores into sterile setae. Fig. 5. Proliferation of conidiophores into sterile seta and secondary conidiophore.

Colonies yellowish brown to brownish, amphigenous, hyphae septate, pale brown to brown. Sterile setae and conidiophores arising laterally from the cells of hyphae, interspersed and aggregated; setae simple, unbranched, thick-walled, long, subulate, dark brown, thick-walled towards the base, becoming paler and paler towards the tip, up to 22-septate, $216–450 \times 5 \cdot 4–9\,\mu$. Sometimes proliferation of setae into sterile setae through cupulate apices. Conidiophores simple, unbranched or branched, short, usually 1-2-septate, pale in colour, with globose fertile tips, $18–54 \times 3 \cdot 6–5 \cdot 4\,\mu$; fertile tip $7 \cdot 2–9\,\mu$. Conidia capitate, produced acropetally from globose tip of conidiophore, one-celled, globose, finely verrucose, pale brown to dark brown, $5 \cdot 4–9 \cdot 0\,\mu$ in diameter. Globose head of conidiophore becoming cupulate after conidia are shed. Conidiophores sometimes branched, proliferating through cupulate apices into sterile setae or into secondary conidiophores.

Slides of this fungus are in the authors' collection in the Botany Department, Banaras Hindu University.

The authors wish to thank Rev. Fr. Dr. H. Santapau, St. X'avier College, Bombay, for rendering the description into Latin and to Prof. R. Misra, Head of the Botany Department, for the laboratory facilities.

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VEGETATION IN THE CATCHMENT AREAS OF RIVERS GANGA AND YUMNA WITH REFERENCE TO THEIR SOIL AND WATER CONSERVATION PROBLEMS

By R. K. Gupta

French Institute, Pondicherry

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River Ganga and Yumna are the two principal rivers of Northern India bringing floods every year in the plains and causing dislocation and misery to millions of people. So, the soil and water conservation problems in the catchment areas of these rivers is a problem that should be taken in hand immediately. In the present paper soil and water conservation problems in relation to the vegetation have been discussed and a few suggestions have been made to check the soil erosions in these areas.

River Ganga originates from Gaumukh glaciers at Gaumukh 6,600 m. (22,000 ft.) and River Yumna from Bandarpunch 6,906 m. (20,720 ft.), within the territory of Tehri Garhwal District, a former princely state, lying in the north-western Himalayas. These two rivers are fed by their numerous tributaries before they reach the plains. The origin of these tributaries is also within the limits of the Himalayas.

Studies on the vegetation in the catchment areas of these rivers have been made by the author in continuation to that already made by Puri and his co-workers (Puri, 1950, 1956) in the adjoining parts of the Himalayas, towards east and north in Kulu and Bashahar. These studies have clearly shown that the distribution of vegetation depends more upon the geology and soil of the place. The oaks are the climatic climax; the conifers come up as a result of biotic influence either artificially by cutting, felling, fire, etc., or by natural means such as glaciation, landslide and avalanches. The conifers show a tendency of progression towards the oak climax and/or preserved in their present state on account of peculiar conditions of rock and soil type and have been called as 'seral' communities.

Vegetation

The catchment areas of these rivers can be divided into (1) The Upper Catchment Areas, (2) The Middle Catchment Areas, and (3) The Lower Catchment Areas.

1. Upper Catchment Area

The limit of the upper catchment area can roughly be fixed above 3,000 m. This area is in the region of low monsoon rainfall and heavy

snowfall. Meteorological data of these regions are not available, and the only recourse is to compare from the available data in other parts of Himalayas, which are also very scanty. Table I gives the rainfall (in mm.) and temperature (in °C.) data available in Kashmir Himalayas.

TABLE I

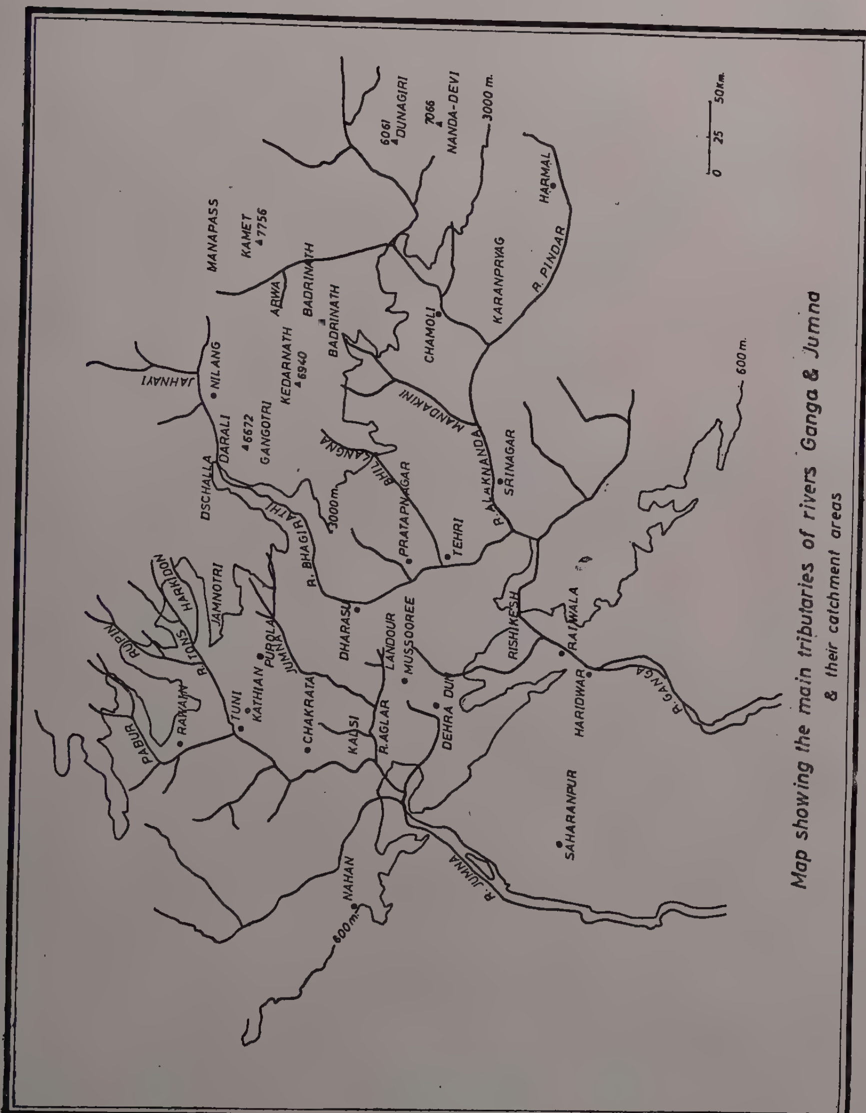
Rainfall and temperature data in the upper catchment areas

(In Kashmir Himalayas)

		J	F	M	A	M	J
Dras ..	3,067 m.	97·3 −15·6	97·3 −14·5	138·2 − 8·5	103·9 − 0·5	61·5 7·8	17·3 13·6
Leh ..	3,516 m.	9·6 − 7·4	7·8 − 5·7	7·1 0·3	5·8 6·0	5·5 10·2	4·5 14·3
		J	A	S	O	N	D
Dras ..	3,067 m.	16·0 16·9	14·0 17·1	17·5 12·5	19·5 5·6	12·4 − 2·7	53·6 −10·7
Leh ..	3,516 m.	11·9 17·3	14·9 17·1	6·8 13·1	2·5 6·9	10·1 0·8	4·8 − 4·4

In the Garhwal Himalayas it has been estimated that the rainfall during July to September at Nitipass (11,464 ft.) amounts to 140 mm. while in winters the snowfall at 4,600 m. is 9 m. and on higher ranges may amount to 19–30 m. The temperature varies with the altitude. Blanford (1889) gives a temperature variation of about 1° F. for every 300 ft. rise in elevation and according to him the mean annual temperature at 11,000–12,000 ft. would be about 42°–45° F. approximately.

Tree vegetation on the morainic and other glacial deposits is of *Abies spectabilis* (D. Don.) Spach. Lind., *Picea smithiana* (Wall.) Boiss, *Abies pindrow* Spach., *Taxus wallichiana* Zucc., *Betula utilis* Don., *Populus ciliata* Wall. and Acers. Shrubs of *Rhododendron campanulatum* D.Don., *Rhododendron anthopogon* D.Don., *Rhododendron lepidotum* Wall., *Salix flabellaris* Anders., *Salix Daphnoides* Villars., *Salix lindleyana* Wall., *Juniperus squamata* Buch-Ham., *Juniperus communis* Linn., *Juniperus wallichiana* Hk.f. are most common. At some places degraded stages of the alpine forests are present. In the early stages *Quercus semicarpifolia* Smith. is the climax community and common shrubs are *Rosa macrophylla* Lindl., *Viburnum cotinifolium* Don., *Viburnum foetens* Decne., etc., with many ferns and other species such as *Anaphalis*, *Indigofera*, *Fragaria*, *Anemone*, *Aquilegia*, etc. On open pastures in moraines, ground flora is of *Anemone rivularis* Buch-Ham., *Prunella*



Map showing the main tributaries of rivers Ganga & Jumna & their catchment areas

vulgaris Linn., *Picrorhiza kurroa* Royle., *Gentiana* sp., *Galium* sp., *Potentilla microphylla* D.Don., *Thymus serpyllum* Linn., *Rumex acetosa* Linn.

Flood plain deposits bear magnificent forests of *Cedrus deodara* Loud. Here *Quercus dilatata* Lind. would be the natural climax vegetation. At places where there is intense grazing, shrubs of *Berberis*, *Cotoneaster*, *Spiraea*, *Rosa* sp. are present. The ground flora is of *Ainsliaea aptera* DC., *Anemone* sp., *Arisaema* sp., *Fragaria vesca* Linn., *Galium* sp., *Viola canescens* Wall., *Strobilanthes*, etc. Near the beds of the streams the deposits are more fertile and bear community of *Almus nitida* Endl., *Ulmus wallichiana* Planch. and *Cornus macrophylla* Wall. On scree deposits wherever the valley is wide, alluvium is covered by species such as *Artemisia* sp., *Daphne bholua* Ham. ex. Don., *Spiraea lindleyana* Wall. and *Arundo donax* Linn.

2. Middle Catchment Areas

The limit of this area can be fixed between 600 and 3,000 m. These are the regions with high monsoon rainfall and small snowfall. Various tributaries of Rivers Ganga and Yumna arise in this region and carry the greatest amount of water during monsoons. This forms the region where Ganga and Yumna receive most of their water during monsoon months.

Table II gives the rainfall and temperature data in Tehri Garhwal and neighbouring parts.

The main rocks in this region are the schist, phyllite, quartzite, etc. The dip slopes are mainly cut into gullies, that nourish the narrow streams. On account of the seepage and bedding planes in the body of the strata, seepage of water weakens the joints and cause landslides.

On the block screes *Quercus incana* Roxb. is the main vegetation associated with a number of broad-leaved species like *Aesculus indica* Colebr., *Litsea umbrosa* Nees., *Ilex dipyrena* Wall., *Cornus macrophylla* Wall., *Rhododendron arboreum* Smith., *Pieris ovalifolia* D.Don., etc. Common shrubs are *Desmodium tiliaefolium* G.Don., *Daphne bholua* Ham. ex. Don., *Sarcococca saligna* (Don.) Muell and Arg., etc. The ground species are *Viola canescens* Wall., *Valeriana jatamansi* Jones, *Pilea umbrosa* Wedd., and ferns. Along the 'nalas' *Cedrus deodara* Loud., *Salix elegans* Wall., *Salix tetrasperma* Wedd. can be seen and at some places *Alnus nitida* Endl. and *Ulmus wallichiana* forms the riverain vegetation.

Places that are greatly disturbed by man have a degraded plant community and *Pinus griffithii* M'Clell. makes its appearance on dry habitats; common shrubs are *Spiraea*, *Berberis*, *Rosa*, etc.

Fine screes formed by the decomposition of phyllite and schist rocks and from slipping of old scree mass are covered by luxuriant vegetation of *Quercus incana* Roxb. and *Quercus dilatata* Lindl. climax

TABLE II

Rainfall and temperature data in the middle catchment areas

(In Tehri Garhwal and neighbouring hills)

		J	F	M	A	M	J	J	A	S	O	N	D
*Tehri ..	692 m.	107·44 12·1	66·04 13·7	40·38 17·7	15·49 22·7	50·54 26·6	82·29 29·6	197·35 28·6	280·92 27·6	88·64 24·1	30·06 19·5	13·20 15·7	16·25 12·4
*Barkot .	1,000 m.	136·39 11·2	85·34 12·4	66·29 16·3	72·44 20·4	68·97 24·4	136·14 27·5	263·14 26·4	354·33 25·4	163·83 22·5	15·49 18·0	12·70 14·9	40·64 11·8
*Dhanolti ..	2 663 m.	25·40 5·1	15·24 5·7	49·78 9·7	16·25 14·4	2·03 16·9	132·08 19·7	281·43 19·2	517·14 18·6	191·26 17·3	319·53 12·6	.. 10·0	3·81 7·1
*Dharasu ..	1,000 m.	99·31 5·1	87·88 5·7	39·37 9·7	62·23 14·4	41·14 16·9	160·02 19·7	234·69 19·2	192·27 18·6	86·86 17·3	9·39 12·6	3·04 10·0	92·96 7·1
*Narendranagar ..	1,000 m.	101·09 11·2	16·76 12·4	68·58 16·3	.. 20·4	272·03 24·4	653·54 27·5	504·44 26·4	239·77 25·4	207·77 22·5	.. 18·0	.. 14·9	.. 11·8
*Purola ..	1,000 m.	19·5 11·2	54·86 12·4	26·16 16·3	45·97 20·4	38·60 24·4	48·76 27·5	326·64 26·4	94·48 25·4	8·63 22·5	.. 18·0	.. 14·9	.. 11·8
Simla ..	2,408 m.	66·3 5·2	74·1 5·7	59·9 10·1	45·9 14·5	64·2 18·5	153·4 19·7	414·0 18·3	428·1 17·6	423·6 16·8	29·9 15·1	13·20 10·6	31·5 7·1
Chakrata ..	2,350 m.	106·42 5·5	116·58 6·1	66·8 10·5	403·86 15·3	62·48 17·9	197·86 19·8	513·58 17·9	507·49 17·7	161·29 17·0	20·82 14·1	10·92 11·0	35·30 7·7
Mussoorie ..	2,313 m.	68·8 5·4	86·6 6·7	57·4 10·9	33·7 15·2	42·4 20·7	223·0 20·2	697·4 18·1	694·4 17·7	252·7 16·6	28·9 14·0	4·3 11·1	35·0 8·0
*Joshimath ..	2,033 m.	75·18 7·0	100·33 7·5	100·58 11·5	57·65 16·1	41·65 18·5	94·48 21·5	200·66 20·7	200·15 20·0	105·91 18·4	32·51 13·8	13·71 11·5	29·21 8·5

* Temperature data based on computations made by Hill (1885).

with other broad-leaved species. The undergrowth is very thick and luxuriant. When the moisture content of the soil becomes less this community may be succeeded by *Pinus griffithii* M'Clell. and *Picea smithiana* Boiss. showing a secondary succession to the oak climax. On moist situations oaks remain prominent.

Pinus roxburghii Sarg. is the dominant community on quartzite scree and do not possess luxuriant vegetation. Wherever there is adequate moisture and soil is finally decomposed, *Pinus griffithii* M'Clell makes its appearance. The ground flora consists of many grasses. On the rocky cliffs and new landslips *Euphorbia royleana* Boiss., *Hypericum cernuum* Roxb., *Pistacia integerrima* Stew., *Ficus* sp., *Rhus cotinus* L., *Berberis lycium* Royle. are present. In the crevices *Taraxacum officinalis* Wigg., *Galium* sp., *Micromeria biflora* Benth., *Polygonum capitatum* Ham., *Androsace lanuginosa* Wall. can be seen.

Flood plain deposits on newly-laid alluvia bear *Alnus nitida* Endl., *Ulmus wallichiana* Planch., *Cornus macrophylla* Wall. and on sandy alluvia seedlings of *Pinus griffithii* M'Clell. are pioneers.

3. Lower Catchment Areas

This zone includes the Siwaliks and the Himalayan forelands below the height of 600 m. Here also the rainfall is heavy during the monsoon months. The heaviest precipitation in the area is along the outer hills wherever the first ridge forms a barrier to exhaust the force of monsoon. According to Hill (1885), the line of greatest rainfall in the Himalayas lies at 1,270 m. (4,165 ft.) above the sea-level and the rainfall here amount to 3·7 times as much as in the neighbouring plains.

Table III gives the rainfall and temperature data in the neighbouring portions of Tehri Garhwal.

Various tributaries of Ganga, Yumna river system arise from these mountains, meeting with the main stream in the plains. There is no snowfall during winter months.

At many places landslips occur both in the strata of quartzite and limestone, and parts of hillsides fall down every year during rains or in winters. The strata of siwaliks bear pure or almost pure communities of *Shorea robusta* Gaertn. On conglomerates tree growth is a coppiced crop of 'sal' with crooked trees, which are also present on sand rock. Ground flora is very limited. There are number of grasses and a dry type of flora exists. On sand-stone 'sal' crop is better developed and in addition to *Shorea robusta* Gaertn, other species like *Anogeissus latifolia* Wall., *Terminalia tomentosa* W. and A., *Terminalia chebula* Retz., *Terminalia belerica* Roxb. and *Bauhinias* occur. Shrub layer is of *Mallotus phillipensis* M.Arg., *Litsea* sp. and others. On slaty rocks clumps of *Hamiltonia suaveolens* Roxb., *Berberis* sp., *Wendlandia* sp. can be seen. Vegetation on quartzite is poor and large stretches are colonised by Bauhinias.

TABLE III

Rainfall and temperature data in the lower catchment areas
(In Tehri Garhwal and Neighbouring hills)

		J	F	M	A	M	J	J	A	S	O	N	D
*Kathgodam ..	1,500 m.	49·78 12·7	73·15 14·8	35·05 19·2	21·59 24·6	58·67 28·9	271·52 32·0	561·84 31·0	576·99 29·7	281·83 25·8	36·57 21·1	9·39 6·5	25·90 12·7
*Kothdwara ..	435 m.	42·92 12·7	48·51 14·8	21·08 19·2	16·76 24·6	25·90 28·9	191·51 32·0	566·42 31·0	547·37 29·7	250·19 25·8	34·54 21·1	7·62 16·5	19·05 12·7
*Haridwar ..	366 m.	75·69 12·7	71·12 14·8	21·16 19·2	2·03 24·6	11·43 28·9	111·25 32·0	274·06 31·0	370·33 29·7	252·47 25·8	21·84 21·1	1·27 16·5	8·12 12·7
Dehra Dun ..	2,239 m.	58·9 12·6	(2·7 14·2	32·0 18·9	16·5 24·6	36·8 27·7	217·2 28·3	66·80 26·6	731·3 26·0	260·7 25·1	32·0 21·3	8·9 16·8	25·9 13·3
*Kirtinagar ..	333 m.	86·36 12·6	7·62 14·2	45·72 18·9	24·13 24·6	10·16 27·7	139·95 28·3	146·81 26·6	222·25 26·0	263·90 25·1	266·95 21·3	.. 16·8	2·79 13·3
*Deoprayag ..	491 m.	88·39 12·7	21·59 14·8	73·15 19·2	37·08 26·6	.. 28·9	101·34 32·0	147·8 31·1	135·6 29·7	78·99 25·8	245·11 21·1	.. 16·5	0·25 12·7
Kalsi ..	610 m.	62·99 12·1	6·09 12·4	78·23 16·3	44·45 20·4	76·96 24·4	64·77 27·5	299·46 26·4	391·42 25·4	166·62 22·5	0·25 18·0	93·72 14·9	.. 11·8

* Temperature data based on computations made by Hill (1885).

Discussion

Glacial moraines are composed of angular blocks lying pell-mell in the matrix having a different composition from place to place, *e.g.*, clay, sand, silt and gravel, etc. These are highly pervious and gets saturated from the water by melting of snow from above. The rainfall at such heights is very low and so the landslips rarely occur. If at all there is a land slip, it is due to the collection of water under these soils, which disturb the angle of repose of the blocks and is of great magnitude. In such areas landslips cannot be checked easily by covering the ground with vegetation and it is the stabilisation of these deposits that can check the occurrence of landslips. On granites question of afforestation does not arise at all and it is only the engineering plans that are needed to drain off the excess of water that percolates slowly in these deposits by melting of snow from above.

Places where morainic deposits have been put under potato cultivation, constitute a regular danger to the destruction of forest areas below, as the soil gets loosened and may result in landslips. Cultivation of potato in such areas should be discouraged as far as possible.

The flood plain deposits occur higher than the present level of the riverbed of Ganga and Yumna and are well stratified, stabler than moraines. Here the seepage of water by percolation is less and the danger of landslips is also comparatively lesser. These are fertile and cultivated at a number of places. When irrigated, landslips of great intensity may occur dislocating villages from their present position. These landslides carry with them huge quantity of rock material which is sometimes sufficient to create temporary bunds in the flow of river. The result is, that the scouring process and the load of silt is increased and bed of the river is raised.

It is therefore desirable that cultivation on such deposits should be discouraged and fruit trees such as apricot, apples and pears should be planted. If at all these deposits are cultivated the fields should be terraced properly so that the soil may not be washed away by the rains. Shifting of cultivation should be discouraged.

In the middle catchment areas whenever there is any landslip on the block screes, huge blocks of rocks fall down and cause considerable damage to the fields. In such areas trees of *Quercus incana*, *Ilex dipyrena*, *Cornus macrophylla* may be planted. In biotically disturbed areas where shrubs of *Berberis*, *Spiraea* and *Rosa* are dominant, biotic interference should be avoided as far as possible and in doing so natural vegetation of oaks may be expected which will conserve the water to a greater extent. In moist gullies *Alnus nitida*, *Ulmus wallichiana*, *Populus ciliata* and *Salix* sp. can be grown successfully.

On fine screes in the rock formations of schist, phyllite, etc., pioneer species to appear is always *Pinus griffithii* and if the area is protected by the animals *Pinus griffithii* is gradually succeeded by *Cedrus deodara*. So at such places these two species are the best for planting.

Bare rocks and screes on quartzite are difficult to plant, since they are most infertile and dry. If such areas are closed a scrub vegetation of *Rhus* and *Capparis* can be expected.

Flood plain deposits do not generally erode under normal conditions of rainfall, since they are covered with natural vegetation and are formed at the flood level of the river. Afforestation of any landslips in these areas will require planting of such species like *Alnus*, *Ulmus*, *Cornus*, etc.

The lower catchment areas can be planted with species like *Shorea robusta*, *Anogeissus latifolia*, *Terminalia belerica*, etc. Bauhinias on quartzite have a great soil conservation value and it appears that merely closing of the area to grazing and cutting would probably cover the entire hillside with vegetation.

Conclusions

In general we can say that water in the Ganga-Yumna river system is derived by the melting of snow in the upper catchment areas during the months when the temperature is high. At these heights some engineering plans should be executed to drain off the excess of water that percolates slowly in the morainic deposits by the melting of snow. Cultivation of potato should be discouraged. Agricultural practices should be discouraged as far as possible, and fruit trees should be planted. The fields should be properly terraced, and shifting cultivation should be abandoned.

The middle and the lower catchment areas are always densely populated. During monsoons most of the water in the rivers is from these areas, that are situated in the region of high monsoon rainfall. Most important in checking the floods is to check the surface and subterranean flow of rain-water. Large stretches of land in these zones are under cultivation or poor pasturage. Various biotic factors such as cutting, lopping and grazing by cattles and sheep have destroyed the vegetation to such an extent that the hills have been left naked with no tree vegetation at all. Bringing all these under forest and fruit cultivation is a problem of human ecology that will have to be tackled soon.

Summary

(1) Catchment areas of rivers Ganga and Yumna have been divided into (1) Upper, (2) Middle, and (3) Lower catchment areas depending upon the monsoon rainfall and winter snowfall.

(2) Vegetation in relation to the geological features of the area have been given.

(3) Suggestions regarding the soil and water conservation in relation to vegetation are presented in the paper.

Acknowledgements

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ECOLOGICAL STUDIES ON THE FUCALES

II. *Fucus spiralis* L.*

By R. Subrahmanyan

Central Marine Fisheries Research Unit, Madras–5

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Introduction

In this final part on the ecological studies on the Fucales, an account is given of *Fucus spiralis* L. which forms a belt of vegetation immediately below that of *Pelvetia canaliculata* Dcne. *et*. Thur., dealt with in the first part (Subrahmanyan, 1960).

Between November 1945 and July 1946, six patches of *Fucus spiralis* were cleared for study when the tides were favourable, one of $\frac{1}{2}$ M^2 area and the rest of 1 M^2 area each. Three of these areas were situated at Port Erin and three at Poyll Vaaish. All the plants visible were removed from them and analysed as in the instance of *Pelvetia*.

It may be mentioned here that Knight and Parke (1950) have made a thorough study covering all aspects of the biology of two other species of *Fucus*, viz., *F. vesiculosus* and *F. serratus*.

Recolonization

As in the case of *Pelvetia* (Subrahmanyan, *l.c.*) the data relating to the normal population of the six unit areas are shown in Table I.

The analyses of the normal population showed that the plants could be broadly classified into size groups. These, when plotted against the number in each category, give curves indicating that the population is a result of several waves of colonization and for areas II, III, V and VI especially, four, five, four and four such epochs respectively were recognizable. From the curves, the concerned size groups for the respective areas are:

Area II: Up to 10, 12–20, 25–35 and 45–60 cm.;
III: Up to 3, 4–14, 17–35, 40–50 and 55–66 cm.;
V: 2–10, 12–16, 19–32, 40–55 cm.; and
VI: Up to 8, 10–16, 18–37 and 50–55 cm.

Very probably, the differences seen between the size groups in the areas is a result of the time of settlement of zygotes and the variation in the rate of growth of the plants.

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* Edited for publication from part of the *Thesis* accepted for the Degree of Doctor of Philosophy of the University of Liverpool, U.K. A copy of the *Thesis* is deposited in the Harold Cohen Library of the University. Part I of these studies on *Pelvetia canaliculata* Dcne. *et* Thur. appeared in the *J. Indian bot. Soc.* **39** (4): 614–630, 1960.

TABLE I

Normal population—Fucus spiralis *L.*—*Number of plants in different size groups*

Area No.	Extent in M^2	Date of clearance	Less than 5 cm.	Size in centimetres							Weight in gm.	Other algae	
				6–10	11–15	15–20	20–25	25–35	35–45	50–65		*Ascophyllum*	*Pelvetia*
I	1	24–11–45	445	152	102	72	35	21	5	..	2240	39 (17 cm.)	1 (3 cm.)
II	1	16–11–45	178	49	38	50	..	98	32	24	5440	..	..
III	1	11– 1–46	123	76	33	62	110	105	41	27	7260	..	..
IV	½	8– 4–46	109	162	73	95	95	116	3	..	4140	16 (8 cm.)	21 (7–27 cm.)
V	1	28– 6–46	1	10	37	77	61	89	86	48	15430	..	
VI	1	9– 7–46	1027	135	133	121	70	50	28	6	6900	..	58 (small ones)

The weight of all the plants cleared from the Areas I–VI was 2,240, 5,440, 7,260, 4,140, 15,400, and 5,900 gm. respectively. The extraordinarily high value for Area V is due to the very large number of reproductive plants present with their large receptacles filled with tough mucilage.

The cleared areas were periodically examined. Some of the areas (I, II, III, IV and V) showed, in the early stages of recolonization, some smaller species of algae growing on the surface, such as *Enteromorpha* sp., *Bangia* sp., *Porphyra* sp., *Lyngbya* sp., and *Ulothrix* sp. Of these, *Enteromorpha* sp., especially, appears to help in the recolonization by providing for the eggs a shelter in the early stages which, unlike in *Pelvetia* (Subrahmanyan, 1957 *b*), have no remnants of the oogonial wall to protect them. Aspects of succession in this zone are discussed later below.

Further, recolonization became emphasized on an area only after a period of reproduction has occurred in the species concerned growing around the area. For example, on an area cleared in January, recolonization of some significance took place only by November next, evidently after the peak of reproduction in the summer.

The final population of the areas, at the end of the period of investigation, is shown in Table II. Details are discussed later below.

One of the areas was recleared for assessing the mass of growth. This was observed to be 692 gm. in 15 months, about 554 gm./year. This may not be very reliable as the plants concerned are juveniles. The rate of production of matter may be higher as the plants grow larger;

TABLE II

Repopulation—Fucus spiralis *L.—Number of plants in different size groups and size attained*

Area No.	Extent in M^2	Last date of observation	Size in centimetres						Max. size in cm.	Period of growth in months	Rate of growth per year	Weight on re-clearance in gm.	Other algae
			Less than 1	1–5	5–10	12–15	15–17	18–22					
I	1	1–10–47	..	810	318	41	5	..	17	22	9.2	..	*Ascophylum* 3 *of* of 3 cm.
II	1	30– –47	..	..	260	..	27	7	20	22	11.0	..	..
III	1	8– 4–47	..	5445	201	35	..	7	21	15	16.0	692	*Aseophylum* 2 *Pelvetia* 4
III	1	1–10–47	..	242	119	..	..	..	8	6	16.0	..	..
IV*	½	1–10–47	..	..	..	..	..	..	29	18	19.0	..	..
V†	I	30– 9–47	22	1	18	..	..	..	..	..	..	..	..
VI‡	1	26– 9–47	..	87	18	..	..	..	10	14	8.5	..	*Pelvetia* less than 1 cm., numerous ; 1 cm. 18 and 3–4 cm., 4

Nature of the Areas:

I. Steep face of rock with clefts, subject to wave action.

II. Sloping flat surface with depressions, at a point of shore of rising terraces which break the force of the waves.

III. Large boulder, sloping, sheltered by much larger boulders and break-water, surface rough.

IV. Two faces of boulder with crevices, sheltered. Vegetation around of *F. vesiculosus* and *Ascophyllum nodosum*.

V. Slightly slopping rocky part of shore, smooth and exposed. *Pelvetia* vegetation at the top and *Ascophyllum* below absent..

VI. Horizontal rough surface, top of a ridge, subjected to wave action.

* Vegetation on this area turned out to be of *F. vesiculosus*. Few *F. spiralis* present. Boulder probably displaced lower to *F. vesiculosus*-zone. Refer text for more details.

† Vegetation negligible as smooth surface does not help establishment of sporelings.

‡ Area near *Pelvetia* zone.

Marked Plants

A large number of plants of varying sizes were also marked to obtain the rate of growth. As mentioned elsewhere (Subrahmanyan, 1960), numbered celluloid discs were employed to mark the plants, 210 plants were marked in this manner; but, only a few survived to furnish data worth mentioning. The majority disappeared in about 5 weeks after marking them. The data collected from this source are presented in Tables III, IV, V and VI.

The data lead to the following inferences: (i) The rate of growth varies from 7·9 to 18·7 cm./year; this is in fair agreement with the data obtained from recolonization; (ii) the rate of growth is not uniform; it is less to begin with and accelerates as the size of the plant increases (compare plant Nos. 1 and 2 with Nos. 121 and 122, Tables IV and VI); (iii) while the smaller plants grow throughout the year, the larger plants which had evidences of fruiting (Nos. 01 and 005, Tables III and IV) appear to show a periodicity in growth similar to what was seen in *Pelvetia* (Subrahmanyan, 1960); and (iv) there is an increase in the girth of the stipe as also in its length (Table VII and Text-Fig. 5).

Table III

Fucus spiralis *L. Marked plants*

Plant No. 01

Date	Length in cm.	Remarks
24–11–1945	27·0	Growth 10 cm. in 4 months. Note growth occurs from November to March; from March to August very negligible
14– 1–1946	31·0	
30– 3–1946	37·0	
6– 8–1947	37·5	

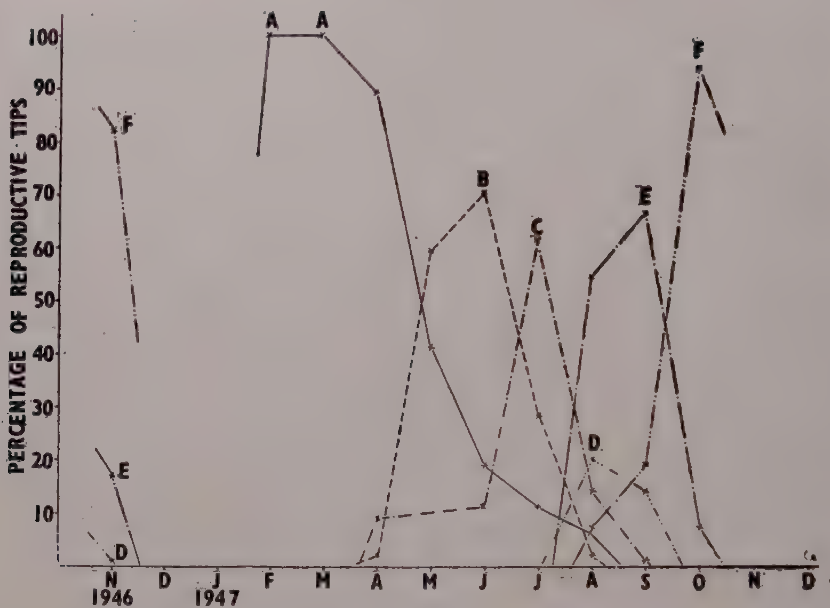
Reproductive Cycle

Period and stages.—Like *Pelvetia canaliculata* (Subrahmanyan, *l.c.*), *Fucus spiralis* has only one reproductive season in a year. The most conspicuous part of this period in the Isle of Man, as witnessed by the presence of well-developed receptacles and discharge of the reproductive bodies lasts from July to September. A detailed study on lines similar to that of *Pelvetia* was carried out from November 1946 to October 1947. Some general information regarding the fruiting periods of the Fucaceae is provided by Rees (1928).

On the basis of the examination of the receptacles made earlier, during the course of the analysis of the normal populations, the cycle of reproduction was divided into six stages as was done for *Pelvetia*. Unlike in *Pelvetia*, where the stages could be clearly and dependably demarcated because of the identical stage of development of all the conceptacles in a receptacle, in *Fucus spiralis*, on the other hand, the determination was rendered difficult as the development of the conceptacles in the receptacles was a long-drawn-out process, conceptacles of all ages occurring in the same receptacle. Nevertheless, by an examination of a large number of receptacles, it was possible to distinguish broadly the six stages mentioned in connexion with *Pelvetia* by taking into consideration the majority of the conceptacles in a receptacle. The stages were designated by letters A, B, C, D, E and F. The receptacles in these stages are shown in the plants figured on Pl. X, Figs. 5, 6, 7 and 8; Pl. XI, Figs. 9 and 10.

In November 1946, when the statistical study was begun, there were present on the plants only degenerating receptacles. In December no receptacles could be observed though careful search was made for them. In the second week of January at Poyll Vaaish and a little earlier at Port Erin, plants were observed with their tips swollen (Stage A). The number of such plants and the number of swollen tips increased and by the end of February in Poyll Vaaish and a little later at Port Erin, Stage B became common followed by Stage C. Up to the middle of July, only these three stages were evident, the later stages among them becoming more numerous, as the earlier stages gave place to them. This period may be considered to be the ripening period for the reproductive bodies; for, towards the end of July dehiscence of oogonia and antheridia begins (Stage D). Soon dehiscence in profusion takes place and the colour of the receptacles also changes (Stage E). After the majority of the conceptacles empty themselves, the receptacles, now orange in colour, begin to break down and give way more or less in the middle (Stage F); consequently, quite a large number of conceptacles situated near the apex and had not dehisced are lost. In fact, Stages D and E follow in such quick succession, that it is often very difficult to determine whether a recptacle is to be placed in Stage D or E.

In Text-Figs. 1 and 2, the above-described sequence of reproduction is represented graphically for plants at the two localities, Port Erin and Poyll Vaaish. It may be seen that Stage A is prominent from January to June; Stage B, April to June at Port Erin, and February to July Poyll Vaaish; Stage C, April to July and March to July respectively at the two localities; Stage D and E, from July to September; and Stage F, September to October. Though the reproductive cycle seems to have set in earlier at Port Erin, the subsequent development of the receptacles appear to be a little faster at Poyll Vaaish when compared with Port Erin. The most striking feature is that the first three stages take about 7 months (January to middle of July) while the subsequent stages are rushed through, taking only 2½ months. It is thus seen that over a greater part of the year the plants show some stage of reproduction and the only month when they can be considered

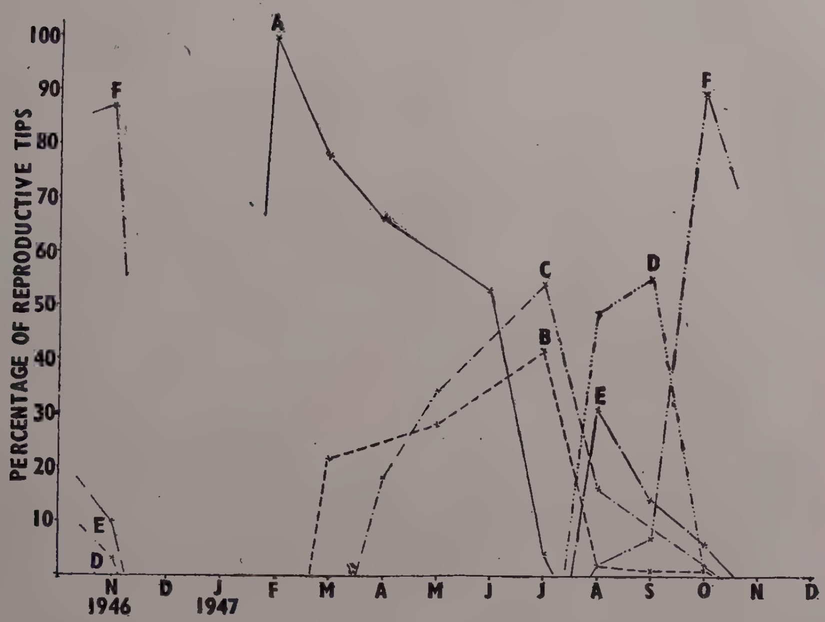


TEXT-FIG. 1. *Fucus spiralis* L. Graph showing the progress of the stages in reproduction during the year of plants at Port Erin. Stage A—beginning of conceptacle development, distinguished by the swollen tips of the fronds; Stage B—conceptacles visible with oogonial and antheridial initials evident; Stage C—oogonia and antheridia clearer and more number of conceptacles with them; Stage D—ripe receptacles with conceptacles showing oogonia with eggs and antheridia with spermatozoids; Stage E—dehiscence of reproductive bodies in profusion: and Stage F—conceptacles empty, receptacles orange in colour and degenerating. For more details refer text.

sterile is December. No such rapidity in the initiation of the conceptacles as recorded for *Pelvetia* (Subrahmanyan, 1957 *a*; 1960) was noticed here, for, the *number* of plants showing such a stage and the *number* of tips involved gradually increased from January onwards and declined in April, when initiation of new conceptacles ceased. The rapid phase of the cycle appear to be confined to Stages D to F, between middle of July and October, particularly to Stages D and E. Probably, the warmth of the summer months hastens the final stages and the discharge of the reproductive bodies.

No internal parasites were observed in the receptacles as in *Pelvetia* (Subrahmanyan, 1957 *a*; 1960). Quite frequently, *Elachistea fucicola* was found growing attached to the receptacles.

It was mentioned above that after a receptacle has completed its rôle, it degenerates. In the present alga, the degneration of the receptacles extends down the frond until the hard midrib is reached, and the latter is left in the form of a spine, which remains as evidence of reproduction. The spines persist and those of one or more seasons can be recognized on a large plant (Pl. XI, Figs. 9 and 11 *s*). In a very old



TEXT-FIG. 2. *Fucus spiralis* L. Graph showing stages in the cycle of reproduction of plants of Poyll Vaaish. Explanation as for Text-Fig. 1.

plant there is very little of frondage and, if there be any, it is confined to the apices, the rest of the plant showing only these *spines* on thin degenerating shoots, the assimilatory tissue having worn away on either side of the midrib progressively. Very frequently, plants devoid of all foliage, consisting only of shoots with spines, may be seen hanging over the rocks. Obviously, these are the ones which have come to a natural end.

General Observations

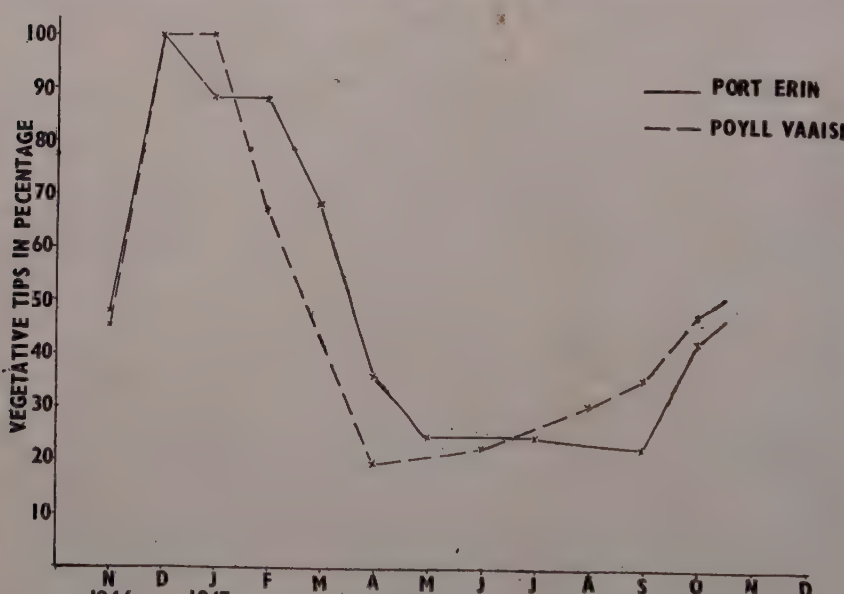
Rate of growth.—An examination of Table II would indicate that recolonization is practically very little on areas which are smooth and exposed (Area V), but better on rough or fissured surfaces. The rate of growth appears to diminish in inverse ratio to the height at which the plants are situated in the zone in relation to tide levels (Areas I and VI). Where the area is sloping but enjoys some protection, the rate is higher (Area III). In a well-sheltered position, the plants grow faster (Areas III and IV). Thus the rate varies from 8·5 to 16 cm./year. In a few instances, some plants growing in the *Fucus vesiculosus* zone below showed 19 cm./year (Area IV). These plants were also of a much more robust appearance with broader fronds.

One interesting point may be mentioned here in connexion with recolonization. Area IV (a boulder) had originally a *Fucus spiralis* vegetation; the recolonised population turned out to be *F. vesiculosus*.

The vegetation around was of *F. vesiculosus* and *Ascophyllum nodosum.* It would appear that the boulder at one time was situated higher up on the shore where *F. spiralis* grew; the displacement of the same into a lower zone and artificial denudation of the vegetation on it, gave *F. vesiculosus* a chance to colonise the area. Naturally also this would have happened, only it may have taken some years.

Observations on individual plants marked for the purpose also showed a rate of growth varying from 7·9 to 18·7 cm., which is in good agreement with values obtained from recolonization studies. The increased growth rate was in inverse ratio to the situation of the plants in relation to the tide levels and in direct proportion to shelter afforded. Further, it was noticed that the rate of growth increases as the plant ages till reproduction sets in, from when on a rhythm sets in as in *Pelvetia* (Subrahmanyan, 1960), vegetative growth alternating with reproduction.

Periodicity in growth.—A definite number of large plants, from Port Erin and Poyll Vaaish, was examined at the beginning of every month from November 1946 to October 1947, and the number of vegetative apices noted. The results are represented graphically in Text-Fig. 3.

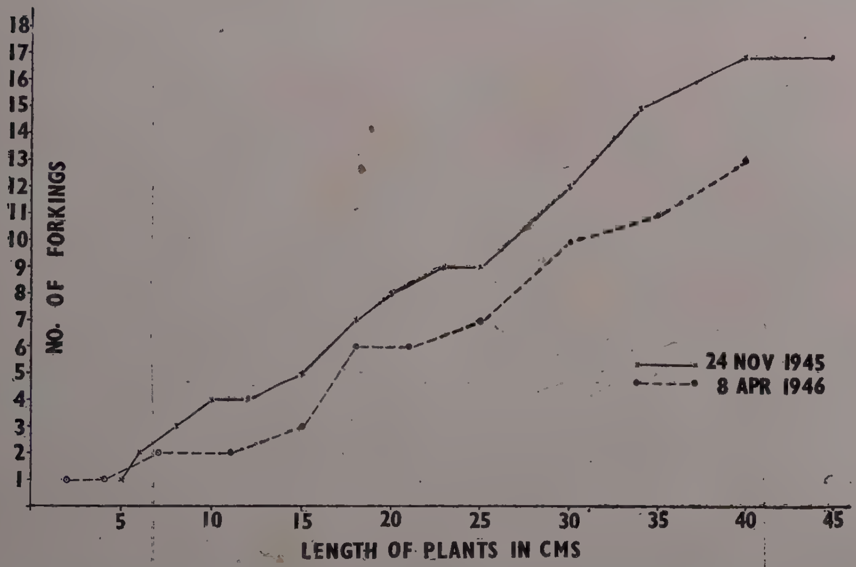


TEXT-FIG. 3. *Fucus spiralis* L. Graph to show periodicity in growth of plants at Port Erin and Poyll Vaaish. Note absence of growth from April to August September. More particulars in text.

The number of tips increases as the fronds dichotomise during growth; with the onset of reproduction in some of them vegetative growth ceases (between April and August) and the vegetative tips present remain quiescent. This quiescent nature is clearly observable because the

sterile tips were at the same level as the receptacular ones adjacent to them. When the reproductive activity wanes, these vegetative tips grow past rapidly and dichotomise as they grow (Pl. XI, Fig. 9). This is very clearly illustrated also by plant No. 01 (Table III) which shows a growth of 10 cm. from November (when it was marked) to March of the following year, but only 0·5 cm. from March to August; the plant No. 005 (Table IV) also indicates this fact somewhat less clearly. Thus, the adults of *Fucus spiralis*, like those of *Pelvetia canaliculata* exhibit a rhythm in their growth, a period of rapid vegetative growth alternating with the period of reproduction.

In this connexion, reference may be made to an interesting relation found to exist between the sizes of the plants and the numbers of forkings. All the plants of the normal population of Areas I and IV (mentioned above) were analysed from this point of view. The results are shown in Text-Fig. 4. The first obvious point is that the number of



TEXT-FIG. 4. *Fucus spiralis* L. Graph to show relationship between size of the plants and the number of forkings for plants from Port Erin and Poyll Vaaish. Note the horizontal stationary portions in the curves which may represent periods of absence of growth. Details in text.

forkings increases as the size of the plant also increases. As it is practically impossible to follow the sequence of growth of all plants of varying sizes in an area, the number of forkings may be considered as a measure of the growth of the plants and the size of the plants a measure of time. Viewed in this light, the graphs reveal an interesting fact. In both the graphs it will be noticed that there are three striking horizontal portions. It is not improbable that these represent the quiescent periods as regards vegetative activity, the population being considered as a whole, and also the extent of the rising portions between

TABLE IV

Fucus spiralis *L.—Marked plants*

Plant No.	Details	12-4-46	18-7-46	4-11-46	2-1-47	30-3-47	1-10-47	Remarks
1	Length in cm.	2·0	3·3	5·2	5·8	6·9	9·2	Growth 7·2 cm. in about 18 months, *i.e.*, 4·8 cm. a year
	Height from base to I internode in cm.		2·8	2·8	2·8	2·9	2·9	
	Dimensions of stipe (elliptical) in cm.			0·15, 0·2	0·16, 0·2	·16, 0·2	0·2, ·26	
2	Length in cm.	2·5	4·5	7·0	7·5	8·5	11·9	Growth 9·4 cm. in about 18 months, *i.e.*, 6·3 cm. a year
	Height from base to I internode in cm.		3·2	3·2	3·2	3·4	3·4	
	Dimension of stipe (elliptical) in cm.		·18, ·21	·23, ·28	·23, ·27	·23, ·30	·24, ·30	
005	Length in cm.	15·0	16·0	19·5	19·8	..	..	Growth 4·8 cm. in about 9 months-from April to July very little but from July onwards higher rate
	Height from base to I internode in cm.		3·3	3·5	3·6	..	..	
	Dimensions of stipe (elliptical) in cm.		·24, ·33	·24, ·3	·25, ·3	..	..	

the horizontal lines which show a proportionate increase with length of time may indicate the acceleration in the rate of growth as the age of the plant increases.

Secondary growth.—In Tables IV and V some measurements are given relating to the height of the first forking from the base of the plant,

TABLE V

Fucus spiralis *L.—Marked plants*

Plant No.	Details	31-7-46	15-11-46	9-4-47	Remarks
59	Length in cm.	4·8	9·8	14·5	9·7 cm. in just 8 months, *i.e.*, 14·5 cm. a year
	Height from base to 1 internode in cm.	2·5	2·5	5·8	
	Dimension of stipe (Elliptical in cm.)	·1, ·14	·19, ·2	·21, ·24	
119	Length in cm.	..	10	13·3	3·3 cm. in nearly 5 months, *i.e.*, 7·9 cm. a year
	Height from base to I internode in cm.		·33	·33	

TABLE VI

Fucus spiralis *L.—Marked individuals—Plant Nos.* 121–139

Plant No.	Details	5-11-46	31-3-47	2-4-47	30-7-47	Growth in cm.	Period months	Rate of growth cm./year
121	Length in cm.	11·5	..	17·0	..	6·5	5	13·2
122	do.	13·8	..	19·5	..	5·7	5	13·6
125	do.	17·0	..	24·8	..	7·8	5	18·7
129	do.	20·5	..	22·7	..	6·7	5	16·0
132	do.	21·2	26·8	..	..	5·6	5	13·2
133	do.	21·0	26·5	..	..	5·5	5	13·2
135	do.	11·0	16·5	..	..	5·5	5	13·2
136	do.	24·0	27·5	..	..	3·5	5	8·4
137	do.	19·5	22·8	..	..	3·3	5	7·9
138	do.	19·0	24·0	..	33·0	14·0	11	15·2
139	do.	17·4	25·0	..	..	7·6	5	18·2

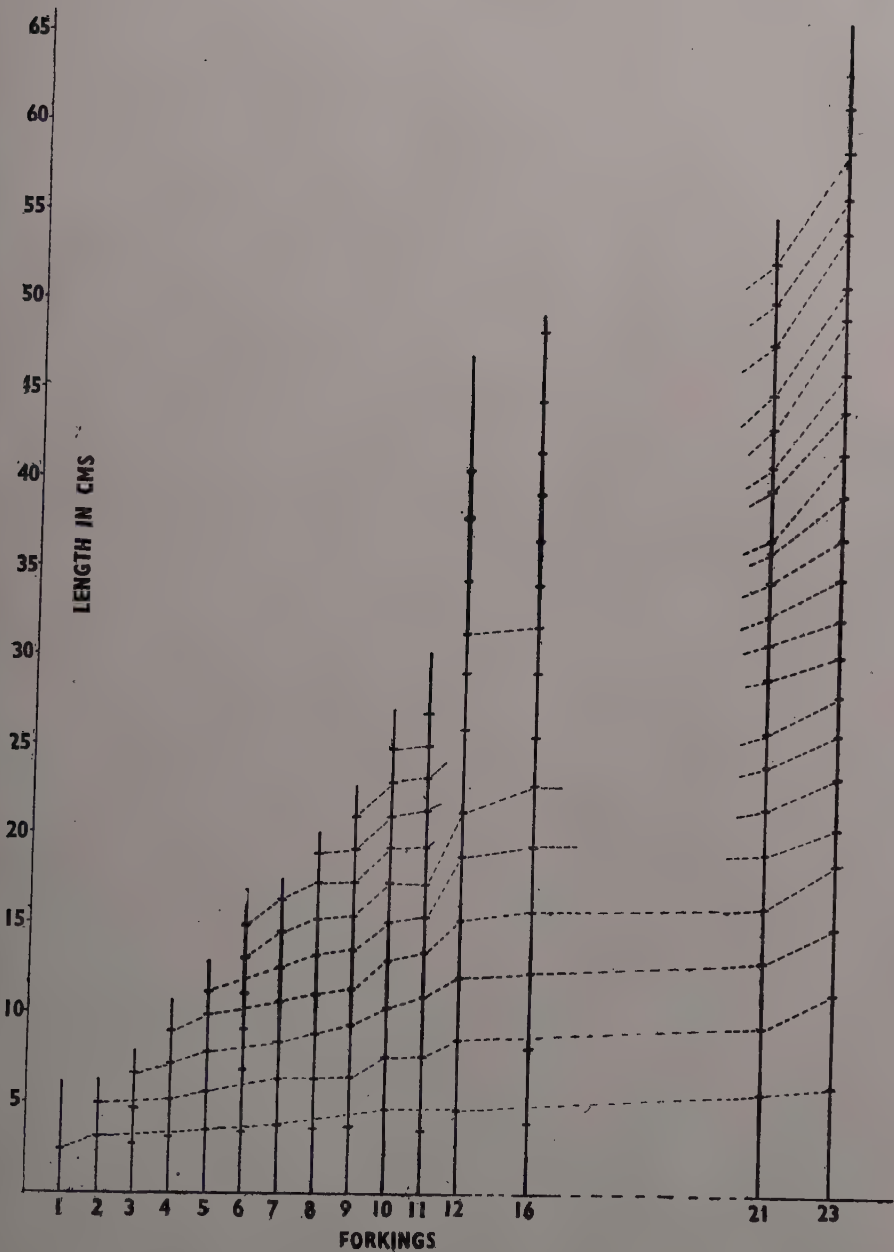
i.e., the length of the stipe, and also the dimensions of the cross-section, the stipe being somewhat elliptical. It may be seen that as the plants grow, there is an increase in the length of the stipe as also in its girth. Detailed investigations are needed to ascertain the mode of increase of length and girth of the stipe, which was, however, beyond the scope of the present investigation. Nevertheless, it may be mentioned here that Pennington (1937) has given some particulars relating to the secondary thickening in this alga (*see also* Reinke, 1876; and Burrows, 1955).

To obtain an idea of the extent of this increase, the length of the stipe and of all the internodes were measured as also the girth of the stipe of plants having 1 forking to 12, 15, 21 and 23. Twenty-five plants were measured in instances up to 12 dichotomies, and as many of the higher categories could not be obtained, the data are not to be regarded as significant beyond 12 forkings. The details are plotted in Text-Fig. 5, the internodal lengths shown being the average figure. It appears that the increase in the size of the plant is not all contributed by apical growth, but is also attributable to secondary elongation and increase of girth of internodes. The increase in girth may be clearly seen from the data presented in Table VII.

TABLE VII

Fucus spiralis *L. Increase in the girth of the stipe with age (length) of the plants*

Length of plants in mm. (Average of 25)	Number of forkings	Girth in mm.	
		Short axis	Long axis
61	1	0·9	1·2
62	2	1·4	1·7
79	3	1·7	2·1
106	4	2·0	2·5
129	5	2·2	2·5
168	6	2·5	2·8
174	7	2·5	3·0
200	8	2·4	3·0
226	9	3·0	3·4
270	10	3·1	3·7
302	11	3·0	3·6
470	12	3·3	3·9



TEXT-FIG. 5. *Fucus spiralis* L. Diagrammatic representation to show secondary elongation of the stipe and internodes as the plants increase in size. Details in text.

Longevity.—The writer is not aware of any published accounts pertaining to this point for *Fucus spiralis*, except for a brief note by Rees (1932). Rees mentions two plants having lasted for three years and five months, and states that the life of the larger Fuci does not exceed four to five years even under sheltered conditions and three to four years under conditions of moderate exposure. Knight and Parke (1950) give particulars relating to *Fucus vesiculosus* and *F. serratus* (*see also* Printz, 1926; Nienburg, 1930; and David, 1943).

The facts disclosed by the study of recolonization of cleared areas and that of individual plants indicate that the rate of growth of *F. spiralis* varies from about 8 to 19 cm./year, depending chiefly on the place of occurrence of the plants in relation to height of tides on the shore. In the *Fucus spiralis*-zone, the maximum size encountered rarely exceeded 60 cm. for plants near the bottom of the zone (Areas II and III) and 40 to 45 cm. at the top of the zone (Area I). Taking into consideration all facts—nature of the surface, density of recolonization, etc.—a mean rate of 8 cm./year for plants at the top of the zone and 13 to 14 cm./year for plants at the bottom of the zone is a fairly accurate estimate. This would give a span of life of 4 to 5 years for the plants. This may also prove to be the time required for the cleared area to return to its former state. To those growing in the *Ascophyllum nodosum*—*F. vesiculosus*-zone also the longevity deduced here may be applicable. A few large individuals collected from this zone in July 1946 were as much as 75–80 cm. long and had frondage only at the apical portions and all of these carried receptacles in all stages of reproduction (Pl. XI, Fig. 10). Evidently, after this season, the plant would have no vegetative "leader" to continue growth. The rate of growth recorded for *F. spiralis* growing in this zone, as already mentioned, is 19 cm./year; and, this fact indicates that these large individuals were only just over 4 years old. From the few that persisted of the many that started life and the disappearance of large numbers of marked individuals it is to be surmised that not a few come to a premature end.

In this connexion, the size groups recognised as a result of the analyses of the normal population of the areas may be mentioned. It is possible that each group represents a wave of colonization and four such epochs seen represent as many years or so of growth on the area. The number of epochs is, perhaps, an indication of the longevity also and this corresponds to the longevity assessed from the rate of growth.

Reproduction and vegetative growth.—It was pointed out under the section dealing with periodicity in growth, that the larger plants exhibit a rhythm in their mode of growth in sharing a pronounced period of rapid growth alternating into a period of reproduction. In the latter season, vegetative activity is very little or completely absent. This rhythm appears to set in once the plants begin to reproduce. The plant shows great similarity to *Pelvetia* in this respect (*refer also* Knight and Parke, 1950, on *Fucus vesiculosus* and *F. serratus*).

Reproduction and age.—The analysis of the normal population showed incidence of reproduction on plants of small sizes, 8 to 10 cm.

and above; and, the percentage of reproducing plants and the numbers of receptacles produced increased with the size of the plants. It is possible that the smaller individuals are the precocious ones or they are really older ones dwarfed in their habit owing to a higher habitat in the zone. Baker and Bohling (1916) also regard the dwarf habit as due to a change in the vertical position of the species relative to the tide. In the light of observations on the rate of growth, these plants, if normal, should be a year old. Data from recolonization showed (Areas II, III and IV) that receptacles appeared on some of the largest plants growing on the area in the second year, and the plants measured about 20 cm. The two large plants collected from the *Ascophyllum*-zone, 27 and 29 cm. in length (two-year old ones) were reproducing for the first time. It is, therefore, permissible to state that normally plants begin to reproduce at the end of the second year of their growth. Again, the largest number of receptacles recorded were on plants (growing in the zone proper) of over 30 cm. and up to 45 cm., *i.e.*, 3 years to 4 years in age approximately. The numbers of receptacles produced begin to decline thereafter. The same sequence described for *Pelvetia* (Subrahmanyan, 1960) appears to hold good for the present alga also, *viz.*, a period of two years of continuous growth; then, with the onset of reproduction, periods of vigorous growth alternating with reproductive periods, this lasting about two years; then senility sets in when vegetative growth declines and in the plant the vegetative apices are increasingly transformed into receptacles; and, when no more vegetative 'leaders' are left, the plant dies out. As stated by Knight and Parke (1950), so long as there is a single vegetative tip left for growth, however distant it may be from the base, the basipetal necrosis of the tissue is arrested at the dichotomy one arm of which is under the control of the functional apex.

Harvesting.—Because of the great variation in the rate of growth met with, it is difficult to state anything definite on this aspect. It may, however, be safe to say that the removal of plants measuring less than 30 cm. from the top of the zone and plants measuring less than 45 cm. from the bottom of the zone is likely to have an adverse effect on the vegetation in the long run. The plants may have to be hand-picked for utilitarian purposes after determining the most useful category as regards their content of economically useful products.

Succession in the Fucus spiralis-*zone.*—In the zone inhabited by the present alga, some of the smaller algae appear to fulfil a rôle in the establishment of *Fucus* on the cleared areas. Of the six areas investigated, five showed this phenomenon and it was well emphasized on Areas II, III and IV. It was seen that the appearance of *Enteromorpha* was invariably followed by an abundance in the number of *Fucus* sporelings which led to the inference that the sporelings were able to establish themselves owing to the protection afforded to them by the felts of *Enteromorpha.*

Apart from affording protection to the sporelings, the *Enteromorpha* may act as a mechanical trap for the eggs which otherwise may get

washed away; for, in *Fucus* the oogonial wall is not so complicated and adapted for functioning like that in *Pelvetia* (*see* Subrahmanyan, 1957 *b*). On the other hand, the eggs are liberated into the water soon after discharge of the oogonium from the conceptacle. They may get entangled among the *Enteromorpha* filaments amongst which they find a humid environment facilitating their growth. *Fucus* does grow even if *Enteromorpha* is absent, but a comparison of the population of *Fucus* before and after the appearance of *Enteromorpha* shows that the population is greatly augmented after the appearance of the *Enteromorpha*.

Some other algae also were recorded on the areas during recolonization—Diatoms, *Bangia*, *Porphyra*, *Ulothrix*, etc. These were found generally at the same time but sometimes one or the other may be absent or all absent. On Area II, Diatoms appeared first with which also were observed two species of blue green algae. *Enteromorpha* appeared later and with it were recorded *Lyngbya*, *Ulothrix* and Diatoms. The Diatoms persisted as epiphytes on *Enteromorpha* while others disappeared. Then, after a few months, *Enteromorpha* alone remained, disappeared for some time, reappeared again after a few months with *Porphyra* and Diatoms. It was noticed that *Enteromorpha* was present in Spring and Summer, and absent in Autumn and Winter. The presence of this alga on a cleared area or on one that is thinly populated during Summer months when reproductive bodies are being discharged by plants around the area will give the sporelings a good start.

The growth of *Enteromorpha* on the areas is not uniform nor is that of *Fucus*. The *Enteromorpha* is seen on the barer parts of the areas and as the *Fucus* gains the upper hand (grows above the felt) the alga disappears. This alga is rarely seen in an area thickly populated by *Fucus spiralis*; if it occurs at all, it is found only as an epiphyte on *Fucus*. It would appear that, in this zone, *Fucus spiralis* is the dominant alga and before this position is attained, there is a "succession" of growths of other algae with their own limited periods of dominance, transitory though it be.

It may also be mentioned here that *Fucus* sporelings always established themselves in abundance among the filaments of *Enteromorpha*; and as the sporelings showed themselves above the filaments, the *Enteromorpha* disappeared from that portion of the area and showed a tendency to establish itself on the barer portions where the events were repeated subsequently. These observations lead one to suppose that *Enteromorpha* helps the establishment of *Fucus* as has been borne out by the studies of other workers also (Bokenham and Stephenson, 1941; Hariot, 1909; Herpin, 1909; Hatton, 1932; Lodge, 1948; Moore, 1939; Wilson, 1925; and Yendo, 1909); they reveal that on a given substratum there is a succession of several forms before the characteristic vegetation of the zone is attained and also that more species may be involved at a lower zone.

Variations.—*Fucus spiralis* appears to be a highly variable form, differing with the habitat. Some of the different forms met with may be briefly mentioned here.

The form occurring in the zone at the stations where the study was carried out belongs to the type and agrees with the description and figure given by Boergesen (1903, pp. 473–74, Fig. 94; 1909–11). This, as stated by Boergesen, "has all its branches, even the topmost distinctly dichotomous, and the latter terminating in receptacles, which are usually more or less swollen and roundish-oval and occur terminally either two on each branch, or cordate if the bipartition is not complete". Figures 5 and 6 in Plate X and Fig. 11 in Plate XI represent the type clearly.

The specimens collected from the *Ascophyllum*-zone in the Isle of Man (Pl. XI, Fig. 10), and those obtained from Cullercoats and Plymouth appear to belong to var. *platycarpa*. This, according to Boergesen, is characterised in that "its main branches are distinctly continued along its whole length and set with short, alternating, lateral branches bearing receptacles". The *F. spiralis* plants which appeared on Area IV to which particular attention was drawn in view of their occurrence among *F. vesiculosus* appear to belong to var. *platycarpa*. This variation appears to be due to a lower habitat on the shore. At Plymouth, the *F. spiralis*-zone is somewhat at a lower level in relation to the tide than in the Isle of Man; the resemblance of the plants there to var. *platycarpa* is therefore of interest.

Another interesting type of plant was found growing at St. Andrews. The specimens were very small and appeared dwarfed and bore receptacles on them. They agreed well with the specimen figured by Boergesen (1903, p. 475, Fig. 96; 1909–11) which he names forma *nana*; he considers this as a dwarf form of forma *typica*. Boergesen recorded this from exposed coasts in the Faeröes (*see also* Boergesen, 1926).

The specimens collected from Langness in the Isle of Man and those from the Mersey had narrower fronds, thinner midribs, and the thallus as a whole was more spirally twisted. The receptacles contained more air than mucilage. There is considerable deposition of mud in these two habitats and characters observed are presumably caused by the habitat. The resemblance of these forms to those described from salt marshes is worth noting (Baker and Bohling, 1916; Naylor, 1936). Such habitat variations have been recorded for other Fucaceae also, *viz*., *Pelvetia canaliculata*, *Ascophyllum nodosum*, *Fucus vesiculosus*, *F. ceranoides* and *F. serratus* (Arcichovskij, 1905; Baker, 1912; Baker and Bohling, 1916; Carter, 1933; Cotton, 1912; Lynn, 1935; Sauvageau, 1908; Skrine, Newton and Chater, 1932; Subrahmanyan, 1960; and Svedelius, 1901). It may be mentioned here that the wide range of variation exhibited by the several species has led some authors (Chalon, 1905; Stomps, 1911) to question the validity of the three species of *Fucus*—*F. spiralis*, *F. ceranoides* and *F. vesiculosus*—and Stomps has figured a very large number of plants to support his contention that all the three species are to be regarded as adaptational varieties

of one species. Baker and Bohling (1916) state that there is no reason to doubt the validity of any of the species mentioned and as a result of detailed study supported by a mass of evidence, they attribute these variations to environmental factors. Burrows and Lodge (1951, 1955) have discussed the problem of variation within the genus *Fucus* with reference to hybrids also.

Summary

Observations covering a period of two years on *Fucus spiralis* in the Isle of Man are described with special reference to cleared areas and marked plants. The rate of growth, longevity, cycle of reproduction, etc., are discussed.

The denseness of recolonization appeared to depend on the nature of the surface and degree of shelter enjoyed by the area. The rate of growth was found to vary from about 8 to 19 cm./year depending on the height at which the alga grew in the zone. The longevity was assessed to be about 4 years. A rhythm in growth was evident in the plants which had started to reproduce, vegetative growth being at a standstill during the reproductive season.

The early signs of reproduction were seen in January; the peak period, as witnessed by the discharge of reproductive bodies is from August to middle of September. The relation of age of plants to reproduction is pointed out.

The succession in the *Fucus spiralis*-zone during recolonization is discussed. The variations noted in the species during the course of the investigation are pointed out and compared with earlier observations.

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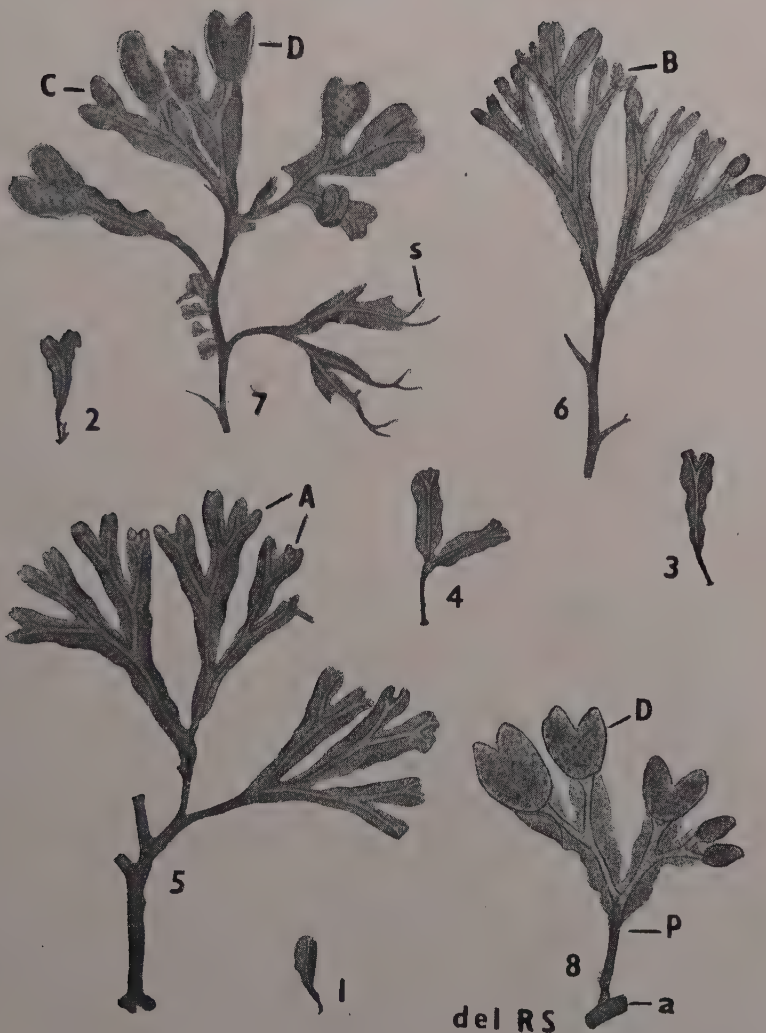
EXPLANATION OF PLATES

PLATE X

Fucus spiralis L. FIGS. 1–8. Figs. 1–4. Young plants illustrating progress in growth. Figs. 5–7. Portions of adult plants showing different stages of reproduction, A, B, C, and D. Plants belong to var. *typica*. Fig. 8. An adventitious shoot with receptacles. All Figs. × ½.

PLATE XI

Fucus spiralis L. FIGS. 9–11. Fig. 9. Shoot of plant with late stages of reproduction E and F. Note also vegetative apices (*v*) grown past the receptacular ones (*r*) which are degenerating. Plant var. *typica*. Fig. 10. A portion of a very large plant showing receptacles in all the stages of development, A, B, C, D, E and F. Plant var. *platycarpa*. Fig. 11. A large plant with evidences of reproduction in the previous seasons '*r*' the most recent one and '*s*' earlier ones. Note vegetative leaders grown past. All Figs. × ¼.



FIGS. 1–8

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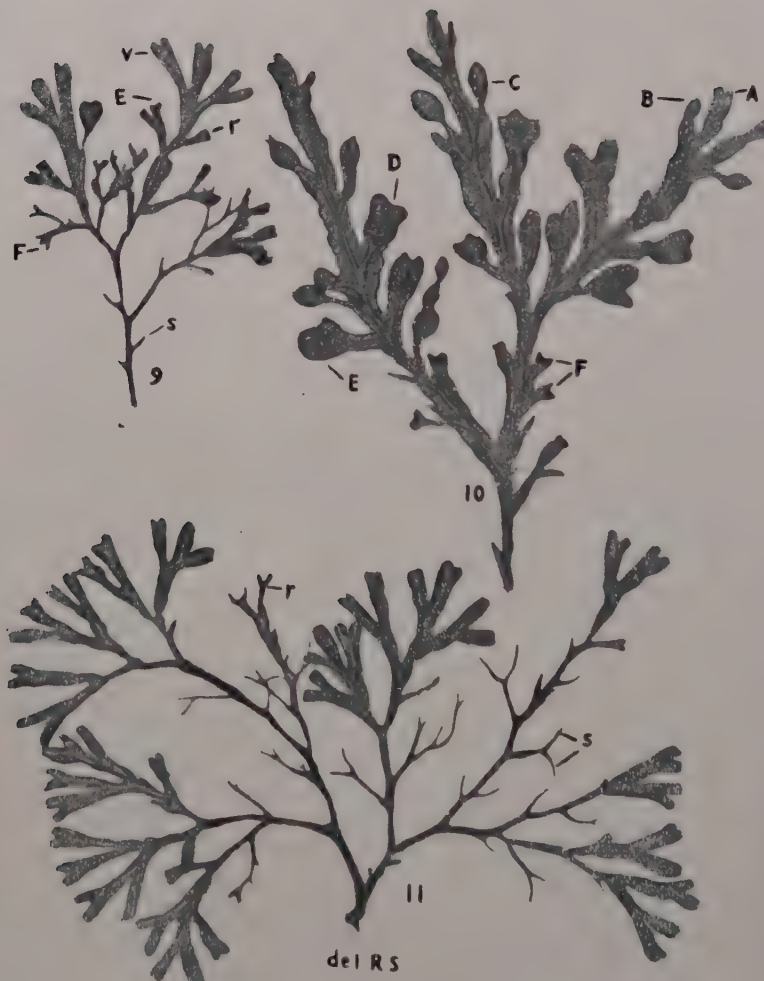

FIGS. 9–11

R. Subrahmanyan

CYTOLOGY OF SOME NORTH-WEST HIMALAYAN URTICACEAE

By B. R. Sharma

*Department of Botany, Panjab University College, Hoshiarpur**

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Introduction

Strasburger (1910) reported on the chromosome numbers in *Elatostema acuminatum* Brongn. *E. sessile* Forst. and *Urtica dioica* L., members of Urticaceae, as all having $n = 16$. His number in *Urtica dioica* was later revised by Meurman (1925) as $n = 24$; Heitz (1926) as $2n = 48$–49; Fothergill (1936) as $2n = 52$ and Love and Love (1942 and 1956) as $2n = 48$. These discordant numbers for *U. dioica* were attributed by Meurman (*l.c.*) and Fothergill (*l.c.*) to the difficult nature of the species for chromosomal studies. The number in *E. sessile* was also improved by Krause (1930 *b* and 1931) from $n = 16$ to $2n = 52$. Further additions to our knowledge of chromosome numbers in this family were made by Negodi (1930) in *Urtica caudata* Vahl (= *U. membranacea* Poir.) and Hamel (1939) in *Pilea cadierei* Gagnepain and Guillaumin. Notable contributions have, however, been made by Krause (1930 *a*, *b* and 1931) in this direction whereas Fothergill (*l.c.*) has recorded a detailed morphology of somatic chromosomes in *Urtica*.

The present investigation relates to chromosome numbers in six species of the family Urticaceae growing at an altitude of about 1980 metres in Mussoorie Hills, of the North-West Himalayas. These species, belonging to four genera, are: *Urtica parviflora* Roxb., *Girardinia heterophylla* Decne., *Pilea umbrosa* Wedd., *P. scripta* Wedd., *Lecanthus wightii* Wedd. and *L. wallichii* Wedd. They are herbaceous forms varying in height from a few cm. as in *L. wightii* to a few metres as in *G. heterophylla*.

Material and Methods

Male flowers of all the species were fixed overnight in the months of July to September 1958 in Carnoy's fixative and squashed in aceto-carmine. Chromosome numbers were counted from diakinesis of pollen mother cells except in *L. wallichii* and *L. wightii* in which the counts were made from M-I and M-II respectively. In the case of *P. umbrosa* root-tip squashes in aceto-orcein were also secured after pretreatment with 0·002 M 8-hydroxyquinoline.

* Present address: Department of Botany, Punjab University, Chandigarh-3.

OBSERVATIONS

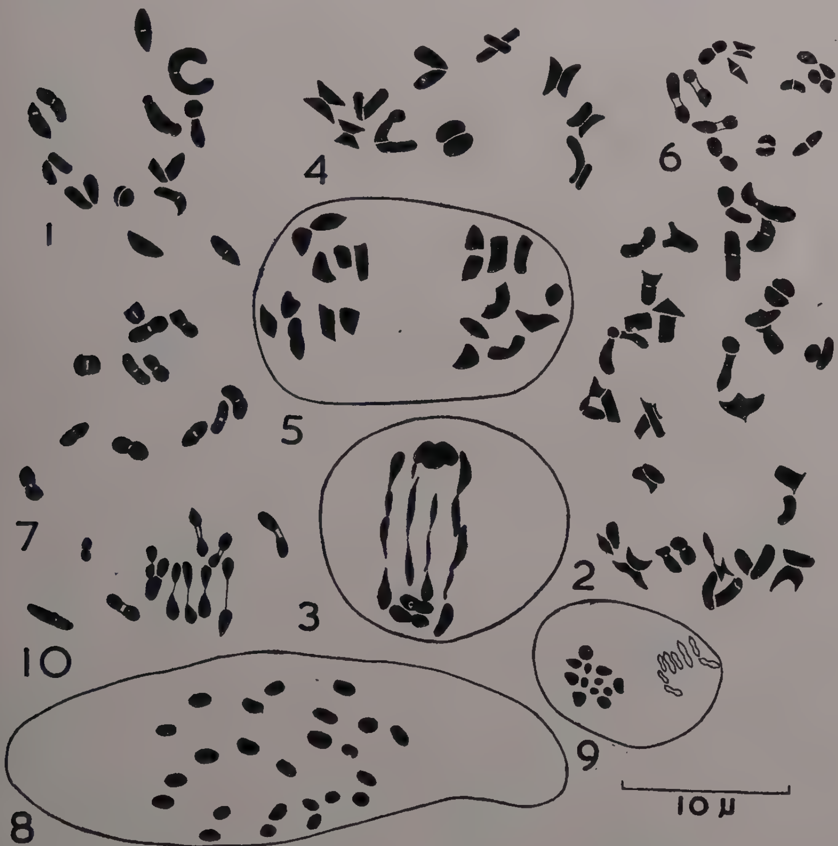
Urtica parviflora Roxb. is a common, tall, herbaceous root-perennial. Considerable variation is noticed in its external characters and chromosome number. According to Hooker (1885) the leaves, which arise in an opposite and decussate manner vary in their shapes from ovate-cordate (through ovate) to ovate-lanceolate (Plate XII, Figs. 1–3). These different forms of leaves are, however, found on different individuals which may be classified into three distinct varieties within the species. These varieties, designated here as L, B and Y, exhibit among themselves other morphological differences and these are summarised in Table I.

TABLE I

Differences in the morphological characters of Urtica parviflora *Roxb. varieties L, B and Y*

Morphological characters	Varieties		
	L	B	Y
1 *Height* of plant ..	0·5–1·25 m.	1–1·5 m.	1–1·5 m.
2 *Stem* :			
(*a*) Branching ..	Comparatively more branched	Little branched	Little branched
(*b*) Thickness ..	Slender	About 1½ times as thick as variety L	About the same thickness as variety B
(*c*) Colour ..	Pale green	Deep green	Deep green
3 *Leaf Lamina* :			
(*a*) Form ..	Ovate–cordate	Ovate–lanceolate	Ovate
(*b*) Length × breadth	7·5 cm. × 4·5 cm.	12 cm. × 3·8 cm. longer but less broad than variety L	12 cm. × 6·4 cm. Almost as long as variety B but broader than either variety L or variety B
(*c*) Colour ..	Pale green	Deep green	Deep green
4 *Stinging Hairs* : ..			
(*a*) Size (of those on the petiole)	±2 mm.	±3 mm.	±3 mm.
(*b*) Distribution on the leaf-lamina. (In the three varieties stinging hairs are distributed all over the upper side but on veins only on the underside)	Minute, numerous on both sides and on the petiole and stem	Fewer but larger in size than those in variety L; more numerous on underside and mainly towards base of lamina	Few but more in number than in variety B; more numerous on upper side than on underside
5 *Inflorescence* (Axillary branched spikes)	Slender	Stouter than variety L	Stout and of same size as variety B

Diakinesis was the most suitable stage for counting the chromosomes in all the three varieties, as at M-I the bivalents are often much compacted, overlap and are, therefore, unsuitable for any critical study. In variety L, with ovate-cordate leaves (Plate XII, Fig. 1) the mother cells were found to possess 13 bivalents unequivocally (Text-Fig. 1) and this



TEXT-FIGS. 1-10. Pollen mother cells (1–7, 9 and 10) and root-tip cell (8). Fig. 1. *Urtica parviflora*, var. L, diakinesis, $n = 13$. Fig. 2. *U. parviflora*, var. B, diakinesis, $n = 26$. Fig. 3. *U. parviflora*, var. Y, anaphase I showing multivalents, not all chromosomes shown. Fig. 4. *Girardinia heterophylla*, diakinesis, $n = 10$. Fig. 5. *G. heterophylla*, anaphase I, $n = 10$. Fig. 6. *Pilea scripta*, diakinesis, $n = 12$. Fig. 7. *P. umbrosa*, diakinesis, $n = 12$. Fig. 8. *P. umbrosa* root-tip cell, $2n = 24$. Fig. 9. *Lecanthus wightii*, polar metaphase II, $n = 12$. Fig. 10. *L. wallichii*, lateral metaphase I, $n = 12$.

number was further confirmed in mother cells at M-II. This number is in conformity with one of the basic numbers reported for the genus *Urtica* ($x = 11$, 12 and 13; Darlington and Wylie, 1955), with the number of chromosomes reported for *U. atrovirens*, *U. grandidentata* ($2n = 26$; Fothergill, 1936), *U. pilulifera* ($2n = 26$; Krause, 1930 *b*

and Fothergill, 1936), *U. urens* ($2n = 26$ and 52; Love and Love, 1942) and *U. cannabina* ($2n = 52$; Fothergill, 1936).

In variety B, with ovate-lanceolate leaves (Plate XII, Fig. 2) diakineses were quite abundant and showed 26 bivalents in a number of mother cells (Text-Fig. 2). This variety is, therefore, a tetraploid. Meiosis is perfectly normal resulting in the formation of well-formed tetrads. Comparison of pollen size of this variety with that of variety L has shown only a slight difference (Text-Figs. 14 and 15). These measure from $10 \cdot 6$ to $16\,\mu$ with an average of $12\,\mu$ in variety L and from 12 to $18 \cdot 6\,\mu$ with an average of $13 \cdot 3\,\mu$ in variety B. There is, however, a considerable difference in the size of stomata in the two varieties (Text-Figs. 11 and 12).

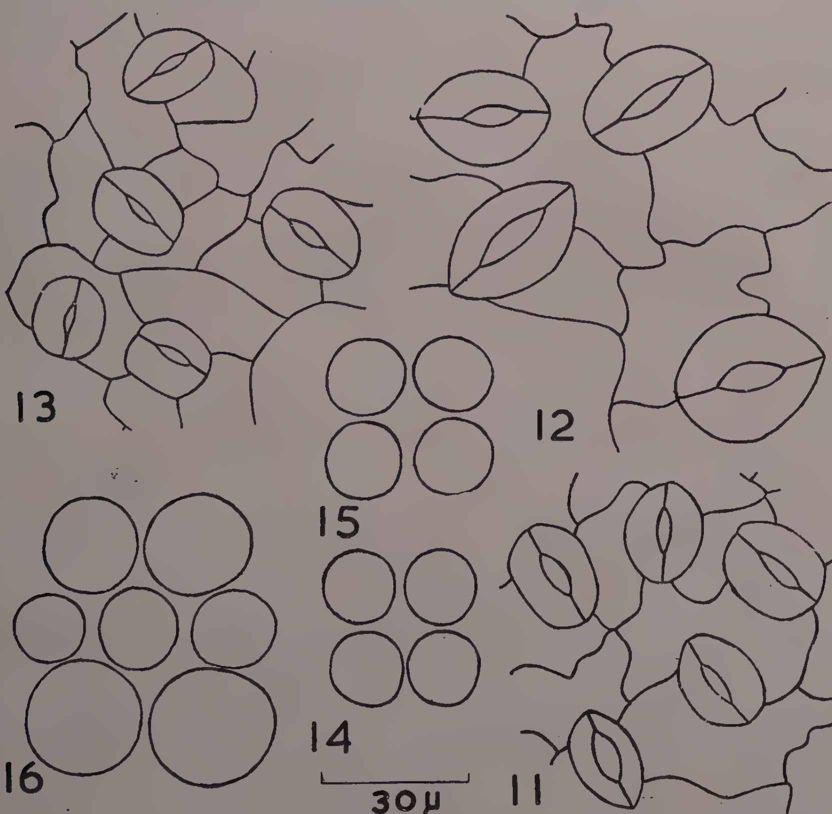
The third variety Y, with ovate leaf lamina (Plate XII, Fig. 3) showed the presence of univalents, bivalents and multivalents (mostly trivalents) at diakinesis. It was not possible to count the chromosome number precisely but the haploid number appeared to be in the neighbourhood of 19–20 on the basis of counts of univalents, bivalents and multivalents. Meiosis is irregular (Text-Fig. 3) and results in the formation of sterile pollen, which show low stainability with acetocarmine, and a wide range of size, from $7 \cdot 9$ to $26 \cdot 3\,\mu$ with an average of $14 \cdot 5\,\mu$ (Text-Fig. 16). Size of stomata in the lower epidermis of the leaf in this variety is nearer to variety L than variety B (compare Text-Fig. 13 with Text-Figs. 11 and 12). Plants belonging to variety Y were, however, found to be rather few and far between, as compared to the other two varieties, L and B.

Girardinia heterophylla Decne. is common in Mussoorie Hills and is heterophyllous. The leaves are entire or incised to varying depths. Plants are taller and more robust than *U. parviflora*. Haploid number of chromosomes is 10 as determined from diakinesis in pollen mother cells (Text-Fig. 4). This was further confirmed from A-I, where 10 chromosomes could be clearly counted at either poles (Text-Fig. 5). This is the first record of chromosome number for the genus. The only other member in the entire family Urticaceae with this chromosome number is *Helxine soleirolli* Req. ($2n = 20$; Krause, 1930 *b*).

Pilea umbrosa Wedd. and *P. scripta* Wedd. are the only two species representing the genus in Mussoorie Hills. Both these herbaceous forms occur commonly along roadside and possess opposite, rather unequal leaves with tail-like tips.

Pollen mother cells in both these taxa showed 12 bivalents at diakinesis (Text-Figs. 6 and 7). Twenty-four somatic chromosomes (Text-Fig. 8) could be counted in the root-tip cells of *P. umbrosa*. The other species of the genus worked out so far are the diploid *P. grandis* Wedd. with $2n = 24$ (Krause, 1930 *b*) and the tetraploid *P. cadierei* Gagnepain and Guillaumin with $2n = 48$ (Hamel, 1939). The only species with discordant number is *P. serpyllacea* Hook. and Arn. in which Krause (1930 *b* and 1931) reported $2n = 52$ which may be a tetraploid on the base number 13.

Lecanthus wightii Wedd., a modest looking species hardly 2·5 to 10 cm. in height, is a succulent and pubescent herb, commonly growing in crevices of rocks and on old walls along with mosses. The plants sometimes have only a single pair of opposite and unequal (obliquely cut) leaves and an axillary, stalked receptacle bearing either male or female flowers. Male flowers are very minute and the youngest among them picked by the naked eye usually contain fully formed pollen grains. Pollen mother cells, in some very young flowers, were isolated with the help of a binocular microscope and it was possible to count 12 chromosomes from the polar view of M-II (Text-Fig. 9).



TEXT-FIGS. 11–16. *Urtica parviflora* varieties L, B, and Y. Stomata from lower epidermis of leaf and pollen grains. Fig. 11. Var. L, stomata; Fig. 12. Var. B. stomata. Fig. 13. Var. Y, stomata. Fig. 14. Var. L, pollen grains. Fig. 15. Var. B, pollen grains; Fig. 16. Var. Y, pollen grains.

Lecanthus wallichii Wedd. was located near water at the Kempty Falls, Mussoorie Hills and was found in association with *P. umbrosa*. This species strikingly resembles *L. wightii* but differs in its larger size which is from 30 to 60 cm. and a longer stalk for the receptacle. Twelve bivalents could be clearly counted from the side view of M-I (Text-Fig. 10).

The haploid chromosome number 12 reported here for *L. wightii* and *L. wallichii* is the first record for the genus.

Conclusions

The most common haploid number is 12 and this is recorded in 4 out of the 6 species investigated. *Girardinia heterophylla* is rather unusual in having $n = 10$. The only other species so far reported in the family Urticaceae with this haploid number is *Helxine soleirolli*. The haploid number 13 is found in *Urtica parviflora* which occurs in three forms, diploid, tetraploid and perhaps a triploid which is far less common than the others in nature. Its sterile pollen, varying in size within wide limits ($7 \cdot 9$–$26 \cdot 3\,\mu$) resulting from irregular meiosis, is suggestive of its hybrid origin. It appears to be a cross between the diploid and tetraploid.

As shown in Table II basic numbers in this family vary from 7, 10, 11, 12, to 13. Hence *Boehmeria argentea*, *B. biloba* and *B. nivea*, *Elatostema sessile*, and *E. sinuatum*, *Myriocarpa densiflora*, *Pellionia begoniaefolia*, *Pilea cadierei*, *P. serpyllacea* (= *P. serpyllifolia*), *Pipturus propinquus* (= *Boehmeria argentea*), *Urtica cannabina*, *U. dioica*, *U. dioica* var. *angustifolia* (= *U. nemorosa*), *U. dioica* var. *kioviensis* (= *U. kioviensis*), *U. gracilis*, *U. parviflora* var. B and sometimes *U. urens* are tetraploids.

TABLE II

Chromosome numbers in Urticaceae

Species	n	$2n$	Author and year
Boehmeria $x = 7, 13$			
argentea Guillem. (compare Pipturus)	—	52	Krause, 1930 *b*
biloba Wedd. (= *Urtica biloba* Hort.)	—	28	Heitz, 1926 (quoted from Krause, 1931)
,, ,,	—	28	Krause, 1930 *b*
nivea Hook. ..	—	28	Krause, 1930 *b*, 1931
,, ,, ..	—	28	Brezlawetz, Medvedeva and Magilt, 1934*
,, ,, ..	—	28	Medvedeva, 1934*
Elatostema $x = 7, 13$			
acuminatum Brongn. ..	16	—	Strasburger, 1910
sessile Forst. ..	16	—	,, ,,
,, ,, ..	—	52	Krause, 1930 *b*, 1931
sinuatum Hassk. ..	—	28	Krause, 1930 *b*

TABLE II—*Contd.*

Species	n	2n	Author and year
Girardinia $x = 10$			
heterophylla Decne. ..	10	—	Author
Helxine $x = 10$			
soleirolli Req. ..	—	20	Krause, 1930 *b*
Lecanthus $x = 12$			
wallichii Wedd. ..	12	—	Author
wightii Wedd. ..	12	—	,,
Myriocarpa $x = 13$			
densiflora Benth. ..	*x*	52	Krause, 1930 *b*, 1931
Parietaria $x = 7, 13$			
erecta ..	—	14	Krause, 1930 *a*, 1931*
,, ..	—	14	Delay, 1947*
judaica L. ..	13	*x*	Krause, 1930 *a*, 1931
officinalis L. ..	—	14	Krause, 1930 *a*
,, var. *angustifolia* ..	7	*x*	,, ,,
ramiflora ..	—	14	Krause, 1930 (quoted from Darlington and Wylie, 1955).
Pellionia $x = 13$			
daveauana Br. ..	13	*x*	Krause, 1930 *a*
pulchra Br. ..	—	26	Krause, 1930 *b*
begoniaefolia Hort. ..	—	52	Krause, 1930 *b*, 1931
Pilea $x = 12, 13$			
cadierei Gagnepain and Guillaumin ..	—	48	Hamel, 1939
grandis Wedd. ..	—	24	Krause, 1930 *b*
scripta Wedd. ..	12	*x*	Author
serpyllacea Hook. and Arn. (= *serpyllifolia* Hort.)	—	52	Krause, 1930 *b*, 1931
umbrosa Wedd. ..	12	24	Author
Pipturus $x = 13$			
propinquus Wedd. (= *Boehmeria argentea* Guillem.) ..	—	52	Krause, 1930 *b*

TABLE II—*Contd.*

Species		n	$2n$	Author and year
Urtica $x = 11, 12, 13$				
atrovirens Req.	..	—	26	Fothergill, 1936
cannabina L.	..	—	52	,, ,,
caudata Vahl (= *membranacea* Poir.)		—	24	Negodi, 1930
dioica L.	..	16	32	Strasburger, 1910 (quoted from Meurman, 1925)
,, ,,	..	—	36	Strasburger, 1910 (quoted from Fothergill, 1936)
,, ,,	..	24	x	Meurman, 1925
,, ,,	..	—	48–49	Heitz, 1926
,, ,,	..	—	48	Love and Love, 1942, 1956
,, ,,	..	—	52	Fothergill, 1936
,, var. *angustifolia* (= *U. nemorosa*)	..	—	52	,, ,,
,, var. *kioviensis* (= *U. kioviensis* Bog.)		—	52	,, ,,
dodartii L.	..	—	24	Heitz, 1926
,, (= *pilulifera* var. *Dodartii* L.)	..	—	26	Fothergill, 1936
gracilis Ait.	..	—	48	Love and Love (unpublished)
,, (= *dioica* var. *procera*)	..	—	26	Fothergill, 1936
grandidentata Moris	..	—	26	,, ,,
kioviensis	..	—	22	Baksay, 1956*
membranacea Poir.	..	—	22	Fothergill, 1936
parviflora Roxb. var. L.	..	13	—	Author
,, ,, var. B.		26	—	,,
,, ,, var. Y.		19–20 ?	—	,,
pilulifera L.	..	—	24	Heitz, 1926
,, ,,	..	13	—	Krause, 1930 *b*
,, ,,	..	—	26	Fothergill, 1936
,, ,,	..	—	24	Delay, 1947*
,, s.v. *balearica*	..	—	26	Fothergill, 1936
urens L.	..	16	—	Strasburger, 1910
,, ,,	..	12	—	Meurman, 1925
,, ,,	..	—	24	Fothergill, 1936
,, ,,	..	—	24	Polya, 1949*
,, ,,	..	—	24, 26 & 52	Love, and Love, 1942, 1956

* From a personal communication of Dr. A. Love.

SUMMARY

Chromosme numbers of six undermentioned species of Urticaceae belonging to four genera and also the basic number for *Girardinia* and *Lecanthus* have been reported for the first time:

1. *Urtica parviflora* Roxb. var. L (with ovate-cordate leaves) $n = 13$
   " " " var. B (with ovate-lanceolate leaves) $n = 26$
   " " " var. Y (with ovate leaves) $n = 19–20$?
2. *Girardinia heterophylla* Decne. $n = 10$
3. *Pilea umbrosa* Wedd. $n = 12$ and $2n = 24$
4. *P. scripta* Wedd. $n = 12$
5. *Lecanthus wightii* Wedd. $n = 12$
6. *L. wallichii* Wedd. $n = 12$

Urtica parviflora has shown chromosomal races, *viz.*, diploid, tetraploid and perhaps a triploid which are morphologically distinguishable.

ACKNOWLEDGEMENTS

My thanks are due to Prof. P. N. Mehra for giving facilities for stay and work in the Summer-School Laboratory in the Mussoorie Hills and for critical suggestions in the preparation of the manuscript, Dr. A. C. Joshi, Vice-Chancellor, Panjab University, for a subsidy to help this investigation, Mr. Brij L. Gupta, Department of Zoology, Panjab University, Hoshiarpur, for helping with the photographs and Dr. Askell Love of Canada for a personal list of chromosome numbers of European Urticaceae with their authors and years.

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EXPLANATION OF PLATE XII

FIGS. 1–3. *Urtica parviflora* varieties L, B and Y. Fig. 1. Variety L. Fig. 2. Variety B. Fig. 3. Variety Y.

FIGS. 1–3

B. R. Sharma

POLLEN GRAINS OF CULTIVATED PLANTS

II. *Bougainvillaea* Comm., *Hibiscus* Medik. and *Euphorbia pulcherrima* Willd.

By P. K. K. Nair

Palynology Laboratory, National Botanic Gardens, Lucknow

(Received for publication on November 30, 1959)

Introduction

In the previous paper of this series the author (Nair, 1960) has outlined the importance of palynological studies of cultivated plants and had dealt in detail with the pollen grains of *Canna*. In the present communication, pollen grains of a few more genera of ornamental plants, namely *Bougainvillaea*, *Hibiscus* and *Euphorbia* (*E. pulcherrima*) have been considered. The polliniferous material has been collected from plants grown in the National Botanic Gardens, Lucknow, and known by the names given here. Pollen preparations have been made according to the method already followed by the author (Nair, 1960), except that in the case of *Hibiscus* the grains prepared by the alcohol treatment have been mixed with the acetolysed ones (prepared according to the method given by Erdtman, 1952, pp. 6–8). The acetolysed grains have been examined for the details of exine structure. The measurements are based entirely on unacetolysed grains.

Bougainvillaea Comm. ex Juss

Bougainvillaea (Nyctaginaceae) is a vigorously growing and heavily climbing South American shrub, extensively grown in India, and is favoured for its attractive brightly coloured bracteal flowers.

The present study takes into account the species *B. glabra* and *B. spectabilis* and also 17 varieties possibly belonging to either of the above species. The pollen morphological observations are summarised in Table I.

Pollen Morphology

General Diagnosis

B. glabra Choisy (Text-Fig. 1, A–D). Grains 3-zonicolpate, $\pm$ spheroidal, about 28 μ in diameter. Apocolpium diameter about 16 μ, colpi about 4 μ wide at the equator, ends pointed, margin slightly thickened. Exine about $2 \cdot 8$ μ thick. Sexine almost as thick as nexine, bacula clear, reticulate. Lumina supported by bacula (LO-pattern) and muri supported by thicker rods than those of the lumina.

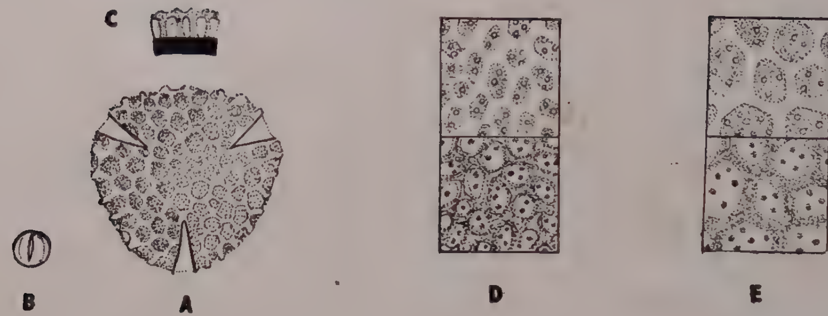
TABLE I

Pollen morphology of Bougainvillaea

Plant name	Pollen morphology						Aborted grains (%)
	Aperture	Size	Shape	Exine			
				Thickness	Ornamentation		
					Brochi large (%)	Brochi small (%)	
1	2	3	4	5	6	7	8
Species *B. glabra* Choisy	3-zonicolpate*	28 μ	Spheroidal	2·8 μ	..	100	..
B. spectabilis Willd	,,	29 × 26 μ	Prolate spheroidal	,,	100	..	..
Varieties *Allic lancaster*	,,	28 μ	Spheroidal	,,	..	100	..
Annie lancaster	,,	(15) 28 μ	,,	,,	..	100	15
Cendriana	,,	31 × 24 μ or 28 μ	Subprolate or spheroidal	,,	15	85	..
Dream	,,	31 × 27 μ or 28 μ	Subprolate or spheroidal	,,	40	60	..

Killie campbell	,,	(15) 27 μ	Spheroidal	,,	..	100	23
Lady wellington	3(4) zonicolpate	34×31 μ or 28 μ	Prolate spheroidal or spheroidal	,,	33	67	..
Lord wellington	3-zonicolpate	31×27 μ or 28 μ	Subprolate or spheroidal	,,	80	20	..
Merrypalmer	,,	28 (41) μ	Spheroidal	,,	..	100	40
Mobqueen	,,	(50×40) 41×34 μ or 28 μ	Prolate-spheroidal or spheroidal	,,	28	72	..
Mrs. A. C. buck	,,	28 μ	Spheroidal	,,	..	100	20
Mrs. mcclean	,,	31×28 μ or 28 μ	Prolate-spheroidal or spheroidal	,,	2	98	5
Partha	,,	28 μ	Spheroidal	,,	..	100	4
President roosewelt	,,	31×28 μ	Prolate-spheroidal or spheroidal	,,	2	98	..
Red glory	,,	30 μ	Spheroidal	,,	..	100	7
Red tinkle	,,	34×31 μ or 28 μ	Porlate spheroidal or spheroidal	,,	85	15	10
Sapii	,,	31×28 μ or 28 μ	Prolate sheroidal or spheroidal	,,	25	75	..
Scarlet queen	,,	28 μ (15–41 μ)	Spheroidal	,,	..	100	18

* Aperture arranged along a circle round the grain.



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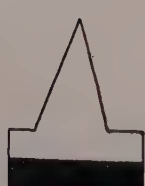

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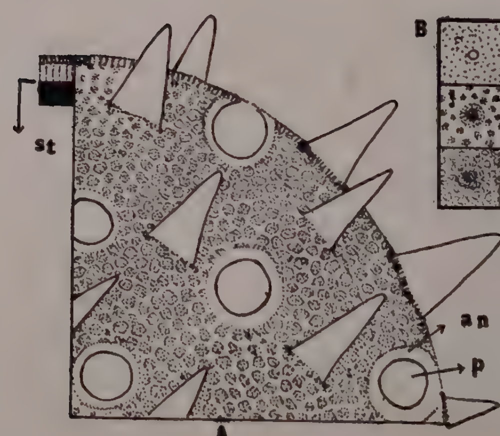

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TEXT-FIGS. 1–7

TEXT-FIGS. 1–7. Fig. 1. A–D. Palynogram of *Bougainvilaea glabra*. *A*. Polar view, showing general surface (× 1,000). *B*. Equatorial view (× 250), *C*. Stratification (× 2,000). *D*. OL-pattern (× 2000). *E*. OL-pattern of *B. splendens* (× 2000). Fig. 2. A–B. Palynogram of *Hibiscus rosa-sinensis*. *A*. Surface view (× 1,000); Quarter grain shown. *B* LO-pattern, (× 2,000). *C*. Pore with a slit in the centre, in *Carneoplenus*. Figs. 3–7. Diagrammatic representation of the optical sections of the exine of pollen grains in *Hibiscus* showing the various excrescence types. 3. pointed; 4 and 6. blunt; 5. spine end knobed; 7. spines on a thick sexinous cushion. (*An*., annulus; *p*., pore; *st*., strata.)

Note.—As in Text-Fig. 2 (above).

Variations

Deviating from the above general diagnosis for *B. glabra*, variations have been noticed in size, shape and exine ornamentation among the varieties. As in *B. glabra* grains are entirely spheroidal in *Allic lancaster*, *Annie lancaster*, *Killie campbell*, *Merrypalmer*, *Mrs. A.C. buck*, *Partha*, *Red glory* and *Scarlet queen* (size varying from 15–41 μ). In the remaining varieties there is a mixture of spheroidal grains with prolate spheroidal or subprolate grains in various percentages (*see* Table I).

Curiously enough, it has been noticed that the spheroidal grains differ from the grains with other shapes in their sculptural details. In spheroidal grains the brochi are smaller (Text-Fig. 1, D) while in the other types, brochi are wider (Text-Fig. 1, E) being almost double the diameter of those of the first type. It is interesting to note that in *B. glabra* all the grains are spheroidal and with small brochi, while in *B. splendens*, they are prolate spheroidal and with larger brochi.

Aborted Grains

Aborted grains have been noticed in various proportions in certain varieties, namely *Merrypalmer* (40%), *Killie campbell* (23%), *Mrs. A.C. buck* (20%), *Scarlet queen* (18%), *Annie lancaster* (15%), *Red tinkle* (10%), *Red glory* (7%), *Mrs. mcclean* (5%), and *Partha* (4%). Incidentally all the above varieties, except *Mrs. mcclean* and *Red tinkle*, are with spheroidal grains.

DISCUSSION

Erdtman (1952) has described the pollen grains of *B. glabra* var. *typica*, which in essentials agrees with the general diagnosis given here for the species. In the varieties of *Bougainvillaea* presently studied, there have been noticed two types of grains marked by their differences in exine ornamentation coupled with shape, one type having smaller brochi and $\pm$ spheroidal shape, and the other having larger brochi and being prolate spheroidal or subprolate in shape. Leaving aside the shape, which may not always be possible to rely upon, the differences in ornamentation and their proportionate representation in the different varieties should provide a clue to the relationship of the varieties. The varieties, *Allic lancaster*, *Annie lancaster*, *Killie campbell*, *Merrypalmer*, *Mrs. A.C. buck*, *Partha*, *Red glory* and *Scarlet queen* probably form one line, all the grains being with small brochi. The remaining varieties, depending upon the percentage of grains with

small brochi form the other group and may be in the following order: *Mrs. mcclean* and *President roosewelt* (98%), *Cendriana* (85%), *Sapii* (75%), *Mobqueen* (72%), *Lady wellington* (67%), *Dream* (60%), *Lord wellington* (20%), *Red tinkle* (15%), along with the species *B. splendens* in which almost all grains are with larger brochi.

The various varieties of *Bougainvillaea* have originated either by mutation or by crossing (Anonymous, 1959). For example, *Merry-palmer* is the result of mutation, and the pollen grains are of one type only, but with about 40% sterility. The mixing of two types of grains, each typified in the species *B. glabra* and *B. splendens*, may be considered to throw light on the nature of the hybrids among the various varieties.

Hibiscus Medik

Plants of *Hibiscus* (Malvaceae) are widely distributed in temperate and tropical countries and are herbs, shrubs or sometimes trees. They thrive well under a variety of conditions and are a much liked garden plant for their beautifully coloured flowers.

The pollen morphology of 6 species and 25 varieties of *Hibiscus* has been studied and the data are contained in Table II.

Pollen Morphology

General Diagnosis

Hibiscus rosa-sinensis Linn. (Text-Fig. 2, A–B).—Grains panporate, spheroidal, about 118 μ, pore circular, diameter about $10 \cdot 5 \mu$, margin slightly thickened. Distance between the apertures, about $17 \cdot 5 \mu$. Exine about 7 μ thick, excluding the excrescences. Sexine, thicker than nexine, surface provided with spines, about 14 μ long. In a majority (forming 85%), the spines are conical with a slightly blunt apex and about $10 \cdot 5 \mu$ in diameter at the base, while in others the spines are divided at the apex, or carry papillose projections from any other region of the spines.

Variations

The above general diagnosis for *H. rosa-sinensis* may be considered typical for the genus. Among the other species and varieties the main differences are in size, shape, aperture and excrescences, and the details are given in Table II.

(i) *Size.*—Taking all the plants into consideration, the size varies on an average from 28–138 μ. Within each variety there is a range in size which is either large as in *H. intermedius*, and most of the varieties of *Hibiscus*, or small as in *H. syriacus*. In many instances the grains have been recognised in two size groups (dimorphic) with a considerable margin between each group. For example, in the variety *Lipstick*, grains with a size of about 110 μ (range 105–119 μ) form 98% and those with smaller size of about 70 μ (range 63–77 μ) form 2%, while in the species *H. calycinus* the size of 23% is 101 μ (range 88–119 μ), and that

TABLE II
Pollen morphology of Hibiscus

Plant name	Apertures: Pore diameter in μ	Apertures: Distance between apertures in μ	Apertures: Annulus* (diameter in μ)	Size: Monomorphic (Size in μ)	Size: Dimorphic I: Size in μ	Dimorphic I: %	Dimorphic II: Size in μ	Dimorphic II: %
Species								
H. calycinus Willd.	7	14	Undeveloped	..	101 (88–119)	23	40 (35–63)	77
H. intermedius† A. Rich.	,,	21	,	28–133	..	..	..	..
H. liliiflorus Cav.	,,	14	10	..	104 (88–112)	74	48 (38–60)	26
H. rosa-sinensis Linn.	10·5	17·5	Undeveloped	..	118 (112–123)	97	38	3
H. schizopetalus Hook. f.	7	14	,,	109 (91–119)	..	..	..	..
H. syriacus Linn.	,,	,,	,,	120 (116–124)	..	..	..	..
Varieties								
Agnescault	,,	17·5	,,	..	126 (123–130)	98	35 (31–45)	2
Alipore beauty	10·5	17·5	,,	..	138 (123–147)	85	49 (35–65)	15
Archeri	7	14	,,	..	101 (91–123)	97	56 (38–68)	3
Australian rose	10·5	28	17·5	..	134 (123–157)	96	45	4
Calleri	7	14	17	..	91 (84–98)	55	44 (35–56)	45
Carneoplenus	5·6	28	11·2	..	56 88	20 41	81 98	23 16
Celestial rose	5	25	Undeveloped	..	107 (98–116)	93	53 (35–65)	7
Cherry	7	28	,,	108 (98–112)	..	..	..	..
Cruentus	5.6 μ (with an ora)	,,	11·2	..	88 98	10 51	81 56	25 14

* Diameter include pores.
† Few grains dimorphic with pointed and blunt spines in the same grain.

TABLE II—*Contd.*

Plant name	Apertures			Size				
					Dimorphic			
	Pore Diameter in μ	Distance between apertures in μ	Annulus (diameter in μ)	Mono-morphic (Size in μ)	I		II	
					Size in μ	%	Size in μ	%
Golden-crown	7	21	Undeveloped	117 (105–129)	..	..	..	..
Juno	,,	,,	,,	..	108 (95–126)	85	47 (42–52)	15
Lipstick	3·5	10·5	,,	..	110 (105–119)	98	70 (63–77)	2
Merry walker	6	25	,,	..	130 (116–140)	97	39 (35–40)	3
Mincanthus	10	14	10	..	70–112	..	..	..
Rosa-malabarica	10·5	17·5	Undeveloped	..	124 (105–133)	73	52 (39–70)	27
Rubroplenus	,,	21	10·5	..	112 (98–123)	30	45 (39–53)	70
Ruther-wilcox	7	,,	Undeveloped	93 (70–98)	..	..	..	..
Sir Henry Egger	,,	17·5	,,	108 (88–140)	..	..	..	..
Snow draft	10·5	21	,,	109 (98–126)	..	..	..	..
Sranora	7	17·5	,,	..	110 (88–126)	82	42 147	17 1
Star of Alipore	,,	,,	,,	..	122 (105–140)	80	56 (39–73)	20
Sweet-heart	,,	14	,,	..	127 (81–126)	96	43 (38–53)	4
Vesuvius	14	16	,,	123 (112–147)	..	..	..	..
Vitifolius	7	17·5	,,	110 (105–123)	..	..	..	..
Viceroy	,,	14	,,	..	96 (77–105)	77	47 (40–55)	23

TABLE II—*Contd.*

Shape	Excrescences								
	Spines					Projection cyclindrical (%)	Verrucate (%)	Divided (%)	Proli-ferate (%)
	Purely pointed (%)	Slightly blunt (%)	Base swollen (%)	Tip swollen (%)	Bent at the tip (%)				
Spheroidal	..	74	..	..	..	..	..	26	..
,,	..	78	..	..	..	..	..	22	..
,,	..	83	6	..	..	..	3	8	..
,,	..	85	..	..	..	..	..	15	..
,,	..	100	..	..	..	..	..	..	..
,,	100	..	..	..	..	..	..	..	..
,,	..	..	..	100	..	..	..	..	..
,,	..	100	..	..	..	..	..	..	..
,,	100	..	..	..	..	..	..	..	..
,,	..	..	70	..	..	20	..	10	..
,,	52	..	..	..	..	..	2	18	28
,,	..	..	..	..	..	..	..	..	..
Sph.; sq.; lin.	..	98	..	..	..	..	..	..	2
Sph.	..	,,	..	..	..	..	..	2	..
,,	..	60	20	5	..	5	10	..	..

TABLE II—*Contd.*

Shape	Excrescences								
	Spines					Projection cylindrical (%)	Verrucate (%)	Divided (%)	Proliferate (%)
	Purely pointed (%)	Slightly blunt (%)	Base swollen (%)	Tip swollen %	Bent at the tip (%)				
Sph.	..	..	..	94	..	..	..	6	..
,,	..	69	..	..	..	21	..	10	..
Sph.; sq.; or lin.	..	90	..	..	..	10	..	..	..
Sph.	..	45	5	..	..	10	38+2 ‡	..	..
,,	..	30	25	..	..	..	35	..	..
,,	..	93	..	..	..	..	..	7	..
,,	14	85	..	1	..	..	..	..	..
,,	..	..	..	..	..	100	..	..	..
,,	24	..	76	..	..	..	..	..	..
,,	..	89	..	..	..	..	..	11	..
,,	..	74	..	..	..	..	..	20	6
,,	..	..	98	..	..	..	..	2	..
,,	..	87	..	..	..	..	..	13	..
,,	..	..	98	..	..	2	..	..	..
,,	100	..	..	..	..	..	..	..	..
,,	..	100	..	..	..	..	..	..	..

‡ 2% with small 'elevations' only.

Abbreviations.—lin., linear; *sph.*, spheroidal; *sq.*, square-shaped.

of 77% is about 40 μ (range 35–63 μ). Large grains with a size of about 147 μ, forming only about 1%, apart from the other size groups with a size of 110 μ and 42 μ, occur in *Sranora*. A few extraordinarily big grains (possibly two grains fused) having a size of about 245 μ have been noticed in *Lipstick*.

(ii) *Shape*.—The grains are generally spheroidal, and sometimes few grains are square-shaped, kidney-shaped or elongate as in *Celestial rose* and *Lipstick* and are generally bigger than normal. Sometimes two grains connected by a narrow passage also occur.

(iii) *Aperture*.—The grains are panporate, and the apertures are circular having a margin either conspicuously thickened (annulus) or faintly delimited. The pore diameter varies from 3·5 μ as in *Lipstick* with a faint annulus to 10·5 μ with a clearly defined annulus (diameter of about 17·5 μ inclusive of the aperture) as in *Australian rose*, or 14 μ with an ill-defined annulus as in *Vesuvius*. The aperture membrane is ornamented ordinarily like the general sexine surface and in *Snowdraft* the encrustation is heavy. The distance between the apertures also varies from 10·5 μ as in *Lipstick* to 28 μ as in *Australian rose*, *Carneoplenus*, and *Cherry*. In the varieties *Merrywalker* and *Carneoplenus*, the pores have been observed to possess an elongate slit (germinal furrow) along its diameter (Text-Fig. 2, C), however is not pronounced in the other species and varieties of *Hibiscus*.

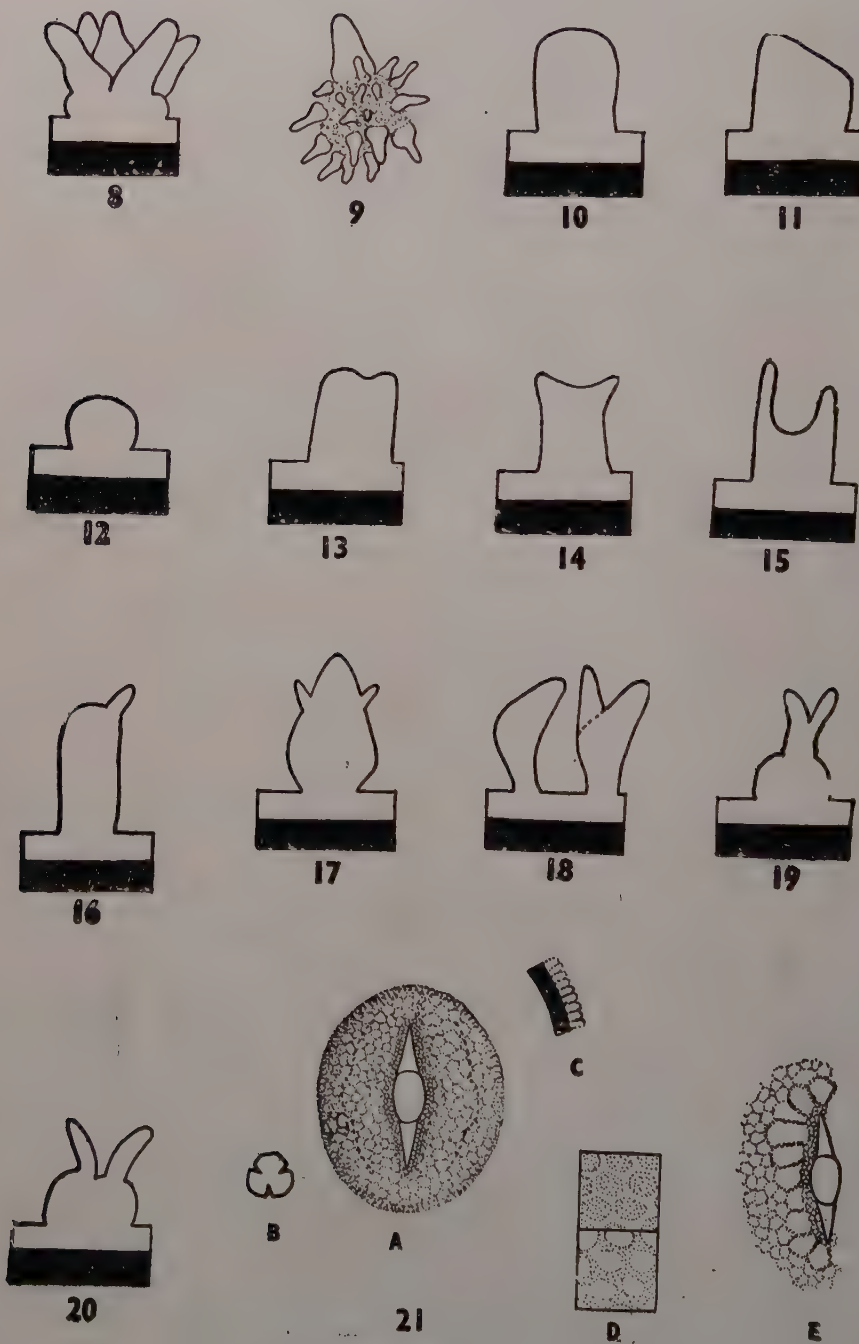
(iv) *Excrescences*.—The largest amount of variations has been noticed in the excrescences. A typical excrescence is a conical spine as in *H. syriacus* having a pointed tip and a broad base resting on a thick sexinous cushion formed by the crowding of the rods which frequently form small sexinous elevations.

In general the spines are conical (Text-Fig. 3), cylindrical, wart-like or divided, and are more or less evenly distributed on the exine surface. Sometimes, the spines are crowded together.

The conical spines may be slightly blunt at the tip, the tip surmounted by a small knob, the stem slightly swollen towards the bottom or at the top but with a narrow attachment, or reduced in length the cushion being prominent (Text-Figs. 4–7).

In the cylindrical spines, the tip is hemispheroidal, flat, or slanting (Text-Figs. 8–20).

The excrescences are wart-like having an unconstricted or constricted base. Such a condition is seemingly by the reduction of a cylindrical excrescence (Text-Figs. 10 and 11). The excrescences are often divided at the distal end or they are provided with papillae-like subsidiary projections, produced from any part of the organ (Text-Figs. 16–18). In some of the cylindrical spines there is often noticed an indentation or invagination at the distal end (Text-Figs. 13 and 14) which in some cases are deep as to produce the bifurcations the two parts of which may be similar or not (Text-Figs. 15, 19, 20). In some others the cylindrical spines carry more branches numbering about 6–10



TEXT-FIGS. 8–21

TEXT-FIGS. 8–21. Figs. 8–20. Diagrammatic representation of the optical sections of the exine of pollen grains in *Hibiscus*, showing the various excrescence types: 8. Five spines on a basal cushion; 9. Proliferations; 10, 11, 13 and 14. Spines with flat ends; 12. Verrucation; 15. Spine showing apical indentation; 16 and 17. Spines with papillate projections; 18. Two spines showing the possible origin of papillas; 19 and 20. Divided spines. Fig. 21. A–D. Palynogram of *Euphorbia pulcherrima*. *A*. Equatorial view (× 1,000); *B*. Polar view (× 250); *C*. Strata (× 2,000); *D*. OL-pattern. 21 E. A colpus and the surrounding region showing the larger lumina in some grains of the varieties of *Euphorbia pulcherrima* (× 1,000).

(Text-Figs. 8 and 9). Similarly there are also small elevations or swellings (Text-Fig. 18) on the stem of the spine which are rudiments of the subsidiary papillae-like projections, as seen in *Carneoplenus*.

In the variety *Juno* 2–6 excrescences occur together (Text-Fig. 8) while in *Calleri*, several projections, large or small, are dispersed on the cushion-like basal thickening (Text-Fig. 9). Again, in *Calleri* there are some abnormal grains in which there are very large cushions formed of sexinous material on which are borne the projections and 'elevations' of different sizes and shapes.

Generally, each grain is marked by one of the above excrescence type. A particular species or variety may have only one type of excrescence in all its grains, or may have grains marked by the different excrescence types, occurring in various proportions. Thus the spines are pointed in all the grains of *H. syriacus*, and the variety *Archeri* and *Vitifolius*, slightly blunt in *H. schizopetalus* and more blunt in the varieties *Cherry* and *Viceroy*. In *H. calycinus*, 74% of the grains are with conical spines and the rest cylindrical and divided. In *H. liliflorus*, 83% are with conical spines with a thinner base, 6% with a thick cushion-like base having a small spine surmounting it, 3% are verrucate and 8% divided. In *Calleri* 52% are with pointed spines, 18% divided, 2% verrucate and 28% 'proliferate'. In *Merrywalker* 45% are with a slightly blunt apex, 10% blunt, 5% with a swollen base but with a narrow attachment, 38% verrucate, and 2% with small elevations.

DISCUSSION

The most striking character in *Hibiscus* and also in other members of Malvaceae is the presence of spines which are sometimes divided, or spinules except for *Geothia cauliflora* and *G. strictiflora*. The grains of *Hibiscus* are also panporate and the exine is made up of a layer of crowded rods forming frequent small sexinous elevations on which the spines are placed.

In the cultivated *Hibiscus*, variations have been noticed affecting size, shape, aperture and excrescences. There has been either one size group (monomorphic) as in *H. schizopetalus*, and the varieties *Cherry*, *Golden crown*, *Ruther Wilcox*, *Sir Henry Eggar*, *Snowdraft*, *Vesuvius* and *Vitifolius*. In *Carneoplenus* the size varies from 56–98 μ and in *Cruentus* from 56–98 μ occurring in various proportions, while in the other plants studied there have been observed two size groups (dimorphic) each separated by a wide margin. Dimorphism in size has been found to

be related to stylar features in *Primula*, the one with shorter style having bigger pollen and *vice versa* (Erdtman, 1952). Joshi (1933) has observed that the size differences in *Argemone mexicana* as the one noticed here is the result of polyploidy.

In shape, pollen of *Hibiscus* are generally spheroidal. Apart from spheroidal grains, square-shaped, kidney-shaped and also linear grains have been marked in the varieties *Celestial rose* and *Lipstick*. The apertures are generally circular, and peculiarly enough the pores in some varieties have been observed to possess an elongate central slit, which feature is not generally found in the pores of panporate grains.

The excrescences also showed remarkable variations, in their nature and occurrence in the various species and varieties and are of great significance in the taxonomy of cultivated *Hibiscus*. In *Archeri* and *Vitifolius* the spines are pointed at the tip, while they are blunt in *H. schizopetalus*, *Alipore beauty*, and *Viceroy*, tip swollen in *Agnescault* and the spines are cylindrical in *Ruther wilcox*. Apart from these, in some grains the excrescences have a swollen base, or are verrucate, and in many cases divided and these occur in various proportions along with other grain types. For example in *Cruentus* in which there is a great size range, 60% are with a slightly blunt tip, 20% with a swollen base, 5% with a swollen tip, 5% cylindrical and 10% verrucate. The relative percentage of the different spine types in a single plant shall form a basis in the taxonomy of these plants (Table II).

A comparative study of the excrescence types gives indication of the formation of appendages or their divisions. The stem of the conical-shaped excrescences bends at the top (Text-Fig. 18) with a bulged curvature on the outer side, from where protrudes an appendage. Sometimes these appendages are produced from the basal enlarged portions. In the cylindrical ones, there appears an indentation on the tip surface of the excrescence, which becomes deeper and produce two equal or unequal branches (Text-Figs. 13–15). "Proliferations" are nothing but projections formed in groups from thick hillocks on the sexine surface.

Euphorbia pulcherrima Willd.

Euphorbia pulcherrima is a tropical American plant largely cultivated in gardens for its brightly coloured bracteate leaves.

Pollen Morphology

General Diagnosis

The pollen morphology of *Euphorbia pulcherrima* and five varieties has been studied and the results are summarised in Table III.

Euphorbia pulcherrima Willd. (Text-Fig. 21, A–D).—Grains 3-zonicolporate, planaperturate in polar view, subprolate, about $39 \times 29\ \mu$. Apocolpium diameter about $17 \cdot 5\ \mu$. Colpi ends slightly blunt, margin thin, oral olongate, about $11 \times 7\ \mu$. Exine about $4 \cdot 8\ \mu$ thick at the

TABLE III

Pollen morphology of Euphorbia pulcherrima

Plant name	Aperture	Exine thickness (μ)	Size and shape					
			Spheroidal		Suboblate		Oblate spheroidal	
			Size (μ)	%	Size μ	%	Size μ	%
Species : *Euphorbia pulcherrima*	(3-zonicolporate)	4·8	..	..	..	..	..	..
Varieties : *Aliporensis*	,,	2·8	..	..	..	..	32×35 or 44×49	26 19
Cream beauty	,,	4·2	37	54	..	..	37×41	6
Pink beauty	,,	4·8	37	10	35×39	14	..	..
Rose queen	,,	3·8	36 or 56	59 1	35×40 or 43×56	6 1	..	..
Yellow dwarf	,,	4·2	38	61	..	..	..	..

Plant name	Size and shape (*Contd.*)				Ornamentation		Aborted grains (%)
	Prolate		Subprolate		Uniformly reticulate	With a region of bigger lumina round the aperture	
	Size (μ)	%	Size (μ)	%			
Species : *Euphorbia pulcherrima*	39×29	100	..	..	100	..	..
Varieties : *Aliporensis*	35×20	55	..	..	100	..	4
Cream beauty	..	..	39×31	40	76	24	6
Pink beauty	..	..	39×30	76	78	22	2
Rose queen	..	..	29×36	33	11	89	6
Yellow dwarf	..	..	37×29	39	82	18	6

centre of the mesocolpium, thinner towards the colpi margins. Sexine thicker than nexine, reticulate, showing an OL-pattern.

Variations

Variation from the above diagnosis has been observed among the varieties. The grains in all plants are provided with three apertures although in *Aliporensis* rudiments of 3 more equatorial apertures have been apparent.

In the different varieties, pollen grains vary in shape, being spheroidal, suboblate, oblate spheroidal, prolate and subprolate, mixed in various percentages in the different varieties. For example, in *Rose queen* there are spheroidal grains with the size 36 μ or 56 μ forming 59% and 1% respectively, suboblate grains having the size $35 \times 40\ \mu$ or $43 \times 56\ \mu$ forming 6% and 1% respectively, along with subprolate ones, with a size $29 \times 36\ \mu$ forming 33%. In *Yellow dwarf* there are only two classes, spheroidal (size, 38 μ forming 61%) and subprolate (size $37 \times 29\ \mu$ forming 39%).

It is in the ornamentation that significant variations have been observed. Normally, as in *E. pulcherrima* the surface is uniformly reticulate. But in most varieties a certain percentage of the grains has been found to be possessed of a region, about 10 μ wide, made of larger reticulations, surrounding the apertures (Fig. 21, E). In *Aliporensis* all the grains are uniformly reticulate, while in *Yellow dwarf*, 82% are uniformly reticulate, and the rest with the other type, but in *Rose queen* only 11% of the grains show the normal type.

Discussion

The exine ornamentation of pollen grains shall be considered to be of basic significance in the taxonomy of *Euphorbia pulcherrima* and its varieties. In *Euphorbia pulcherrima*, pollen grains are uniformly with small reticulations, and this feature is shared by the variety *Aliporensis*. In other varieties, there has been found a certain percentage of grains with broader reticulations around the aperture. Based on the percentage of grains with uniform and small reticulations as in the parent species, the varieties of *Euphorbia pulcherrima* shall be placed in the order, *Aliporensis* (100%), *Yellow dwarf* (82%), *Pink beauty* (76%), *Cream beauty* (76%) and *Rose queen* (11%).

Summary

Pollen morphology of 2 species and 17 varieties of *Bougainvillaea*, 6 species and 25 varieties of *Hibiscus* and 5 varieties of *Euphorbia pulcherrima* has been investigated.

Variations in pollen have been noticed in the shape and exine ornamentation in *Bougainvillaea*, aperture and excrescences in *Hibiscus*, and exine ornamentation in *Euphorbia pulcherrima*. The frequency of pollen variations among the varieties may be taken to interpret the interrelationship among the varieties of a genus,

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STUDIES IN MELIACEAE

IV. Floral Morphology and Embryology of *Azadirachta indica* A. Juss.—A Reinvestigation

By N. C. Nair and Kusum Kanta*

Department of Botany, Birla College, Pilani, India

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The placentation, and early endosperm development in *Azadirachta indica* have been described in earlier communications (Nair, 1956 *a*, *b*). The development of the gametophytes and embryo has been partially studied by Garudamma (1956, 1957). Garudamma's observations may be summarized as: The sporogenous tissue in the anther consists of a row of cells in each locule; the pollen grains are shed at the bicelled stage; the ovular archesporium consists of a single cell and the development of the embryo-sac conforms to the Polygonum type; and, the development of the embryo falls under the fifth group belonging to the third megarch type in the first period of the embryogenic system of classification of Souèges (1939).

Since our observations show some differences the record of these was considered desirable.

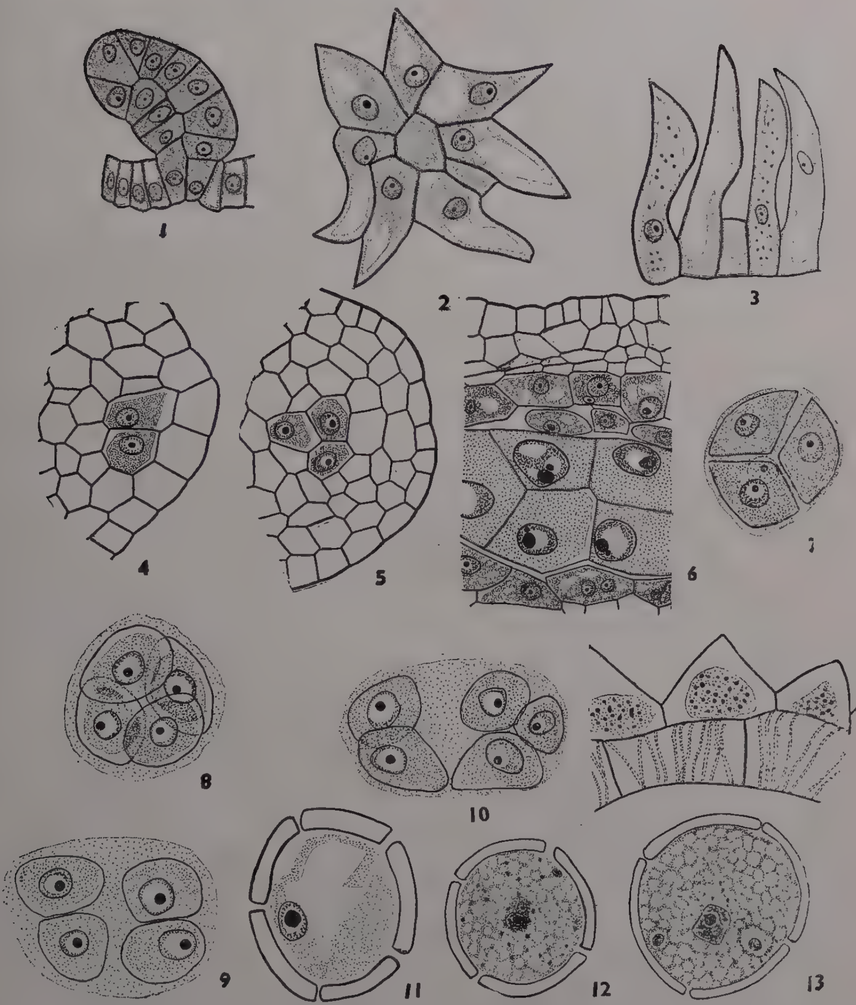
Material and Methods

Azadirachta indica belongs to the tribe Melieae (Hooker, 1875). This tree is cultivated all over India because of its medicinal properties. The material for the present study was collected in Pilani and fixed in formalin-acetic-alcohol in March to July 1956. They were dehydrated in ethyl alcohol xylol series and embedded in paraffin. Sections cut at 8–14 μ thickness were stained in Heidenhain's iron-alum haematoxylin counterstained with fast green. Acetocarmine smears were tried to study microsporogenesis. Whole mounts of embryo-sacs cleared in lactophenol and stained with acetocarmine facilitated a comparative study of endosperm and embryo.

Flower

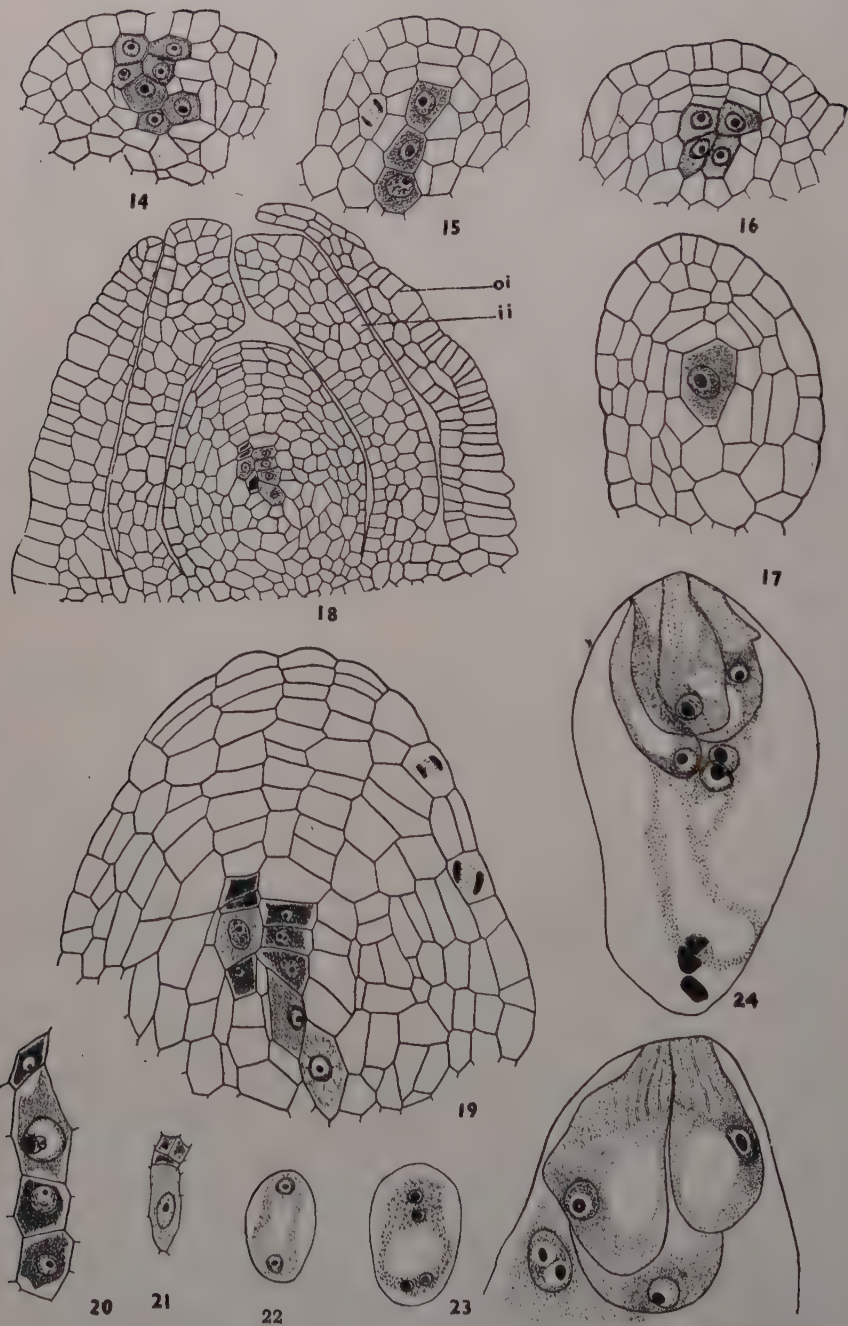
The plant begins to flower in February and the fruits ripen in June-July. The floral parts arise in acropetal succession as has been reported by Garudamma (1957). The bisexual and pentamerous flower has five free imbricate sepals and petals each, a fluted staminal tube slightly dilated at the base and apex and possessing ten dithecous introrse anthers within the fimbriate mouth, an annular nectariferous intra-staminal disc, and a tricarpellary gynoecium. The ovary is trilocular

* Present address: Botanical Survey of India, Dehra Dun, and Department of Botany, University of Delhi, Delhi, India.



TEXT-FIGS. 1–13. Fig. 1. Glandular hair, × 1,500. Fig. 2. Stellate hair, × 1,500. Fig. 3. Unicellular hair, × 1,500. Fig. 4. Part of anther in T.S. showing hypodermal archesporium, × 1,500. Fig. 5. The same showing sporogenous cells and parietal cells, × 1,500. Fig. 6. Part of anther in L.S. showing microspore mother cells and wall layers, × 1,500. Figs. 7–9. Microspore tetrads × 1,500. Fig. 10. A pentad of microspores, × 1,500. Fig. 11. Uninucleate pollen grains, × 1,500. Fig. 12. Two-celled pollen grain, × 1,500. Fig. 13. Part of mature anther, × 1,500.

at the base becoming unilocular in the ovule-bearing region. Each carpel bears two ovules on parietal placentas (*see* Nair, 1956 *a*). Only one ovule develops into the seed. The ovary is continued into a long



TEXT-FIGS. 14–25

TEXT-FIGS. 14–25. Fig. 14. Ovular archesporium, × 1,500. Figs. 15 and 16. L.S. nucellus showing sporogenous cells, × 1,500. Fig. 17. L.S. ovule showing megaspore mother cell, × 1,500. Figs. 18–19. L.S. ovule at the tetrad stage, × 950. Figs. 20–21. Linear and T-shaped tetrad, × 1,500. Figs. 22–24. 2-, 4- and 8-nucleate embryo-sacs, × 1,500. Fig. 25. Upper portion of a mature embryo-sac showing egg apparatus and secondary nucleus, × 1,500.

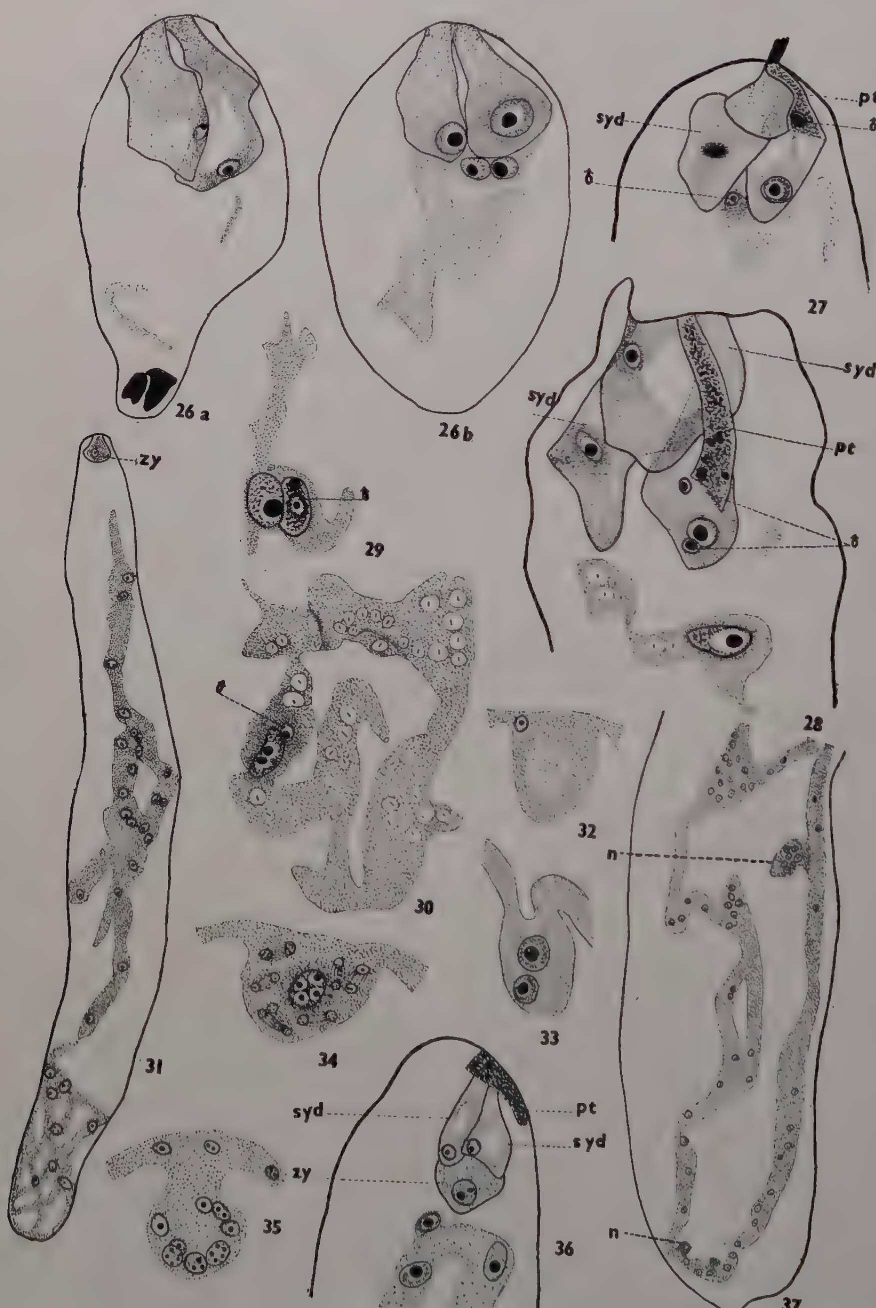
style provided with triradiate canal lined with glandular cells. Secretory cells are present on the ovary wall and disc. During post-fertilization stages they enlarge and become vacuolated. In the pedicel and outer surface of the calyx are present glandular, stellate, and unicellular hairs (Text-Figs. 1–3).

MICROSPORANGIUM AND MALE GAMETOPHYTE

According to Garudamma (1957) there is only a single row of sporogenous tissue in the longitudinal section of the anther. However we have observed a hypodermal archesporium of two to three rows of cells in each anther lobe (Text-Figs. 4, 5). The archesporial cells cut off a primary parietal layer which by repeated anticlinal and periclinal divisions gives rise to a fibrous endothecium, two to three middle layers, and a secretory tapetum (Text-Figs. 5, 6). At places the tapetal cells undergo periclinal divisions and become two-layered (Text-Fig. 6). Garudamma (1957) has reported that the tapetal cells are two to four-nucleate and sometimes the nuclei fuse to form polyploid nucleus. In our material the tapetal cells remain binucleate throughout. Binucleate tapetum has also been reported in *Cipadessa baccifera* (Narayana, 1958). The tapetum completely disappears at the two-celled stage of the pollen grains. In the mature anther only the endothecium and the papillate epidermis remain intact (Text-Fig. 13).

The microspore mother cells undergo reduction divisions in a simultaneous manner. Cytokinesis takes place by furrowing and the tetrads are mostly tetrahedral (Text-Fig. 7). Decussate and isobilateral tetrads are also present (Text-Figs. 8, 9). The microspores are liberated by the disintegration of the mucilagenous sheath surrounding them. A few cases of pentads have been observed (Text-Fig. 10) in which one or two of the spores are smaller than the rest. Polyspory has also been reported in *Naregamia alata* and *Melia azedarach* (Nair, 1959 *a*, *b*).

The young microspore has a large nucleus and dense cytoplasm. As it enlarges a vacuole appears in it and the centrally placed nucleus takes a place close to the wall (Text-Fig. 11). It divides to produce a generative cell (Text-Fig. 12). Garudamma (1957) reports that the pollen grains are shed at the two-celled stage. But in our material they are three-celled at the time of shedding (Text-Fig. 13). In Meliaceae, three-celled pollen grains are recorded in *Sandoricum koetjape* (Juliano, 1934), *Naregamia alata*, *Melia azedarach*, *Sandoricum indicum*, *Cedrela serrata* and *C. toona* (Nair, 1958, 1959 *a*, *b*, *c*). The vegetative nucleus takes a deep stain and has an irregular shape. Due to the presence of abundant reserve food material the nuclei are often masked. The pollen grains have thick, smooth exine and a thin intine. The number of germ pores was found to vary from three to nine, the



TEXT-FIGS. 26–37

TEXT-FIGS. 26-37. Fig. 26 *a*, *b*. Abnormal embryo-sac from two consecutive sections. Explanation in text, × 1,500. Figs. 27, 28. Upper portions of embryo-sacs showing fertilization stages, × 1,500. Figs. 29–30. Triple fusion, × 1,500. Fig. 31. Embryosac showing zygote and free nuclear endosperm, × 1,500. Figs. 32–35. Endosperm nodules, × 1,500. Fig. 36. Upper portion of a fertilized embryo-sac showing free nuclear endosperm, zygote and intact synergids, × 1,500. Fig. 37. Chalazal portion of a fertilized embryo-sac showing free nuclear endosperm and endosperm nodules, × 750.

(*ii*, inner integument; *n*, endosperm nodule; *oi*, outer integument; *pt*, pollen tube; *syd*, synergid; *zy*, zygote.)

common number being four (Text-Figs. 11–13). Similar variations in the number of germ pores have been observed in *Cedrela* (Nair, 1959 *c*). A large number of pollen grains are small and their nuclei degenerate. These grains stain very lightly and are sterile. Sometimes the entire pollen grains in an anther may degenerate.

MEGASPORANGIUM AND FEMALE GAMETOPHYTE

The primordium of the crassinucellate, anatropous, and bitegmic ovule is erect at first but soon becomes anatropous. At the tetrad stage both the integuments are very well advanced (Text-Fig. 18). The integuments are two to four-layered. In the micropylar region the inner integument has five to six layers of cells. The inner integument forms the micropyle. The funicular vascular strand extends up to the chalaza. A parietal tissue of six to seven rows of cells is produced by the division of the primary parietal cell (Text-Figs. 14–19). Garudamma (1957) missed the division of the nucellar epidermis. In our material the nucellar epidermis undergoes periclinal divisions to produce a cap of three to four cells thick (Text-Figs. 18, 19). A nucellar cap is also known in *Sandoricum koetjape* (Juliano, 1934), *Aglaia* sp. (Wiger, 1935), *Naregamia alata*, *Melia azedarach*, *Sandoricum indicum* (Nair, 1958, 1959 *a*, *b*) and *Cipadessa baccifera* (Narayana, 1958). At about the mature embryo-sac stage some of the nucellar cells disintegrate to form a mucilagenous substance surrounding the embryo-sac. This mucilage becomes very prominent during post-fertilization stages.

Garudamma (1957) observed a single-celled ovular archesporium but in our material an archesporium of six to eight cells arises in the hypodermal layer (Text-Fig. 14) of which only one usually develops further (Text-Fig. 17). Sometimes two, three or even more cells may develop into megaspore mother cells (Text-Figs. 15, 16). The mother cells may lie in a linear row or lie side by side. The megaspore tetrads are usually linear (Text-Fig. 20). Sometimes T-shaped tetrads were also observed (Text-Fig. 21). In several cases two tetrads were found to lie side by side (Text-Figs. 18, 19). Usually the chalazal one functions (Text-Fig. 21). In some cases the second and third megaspores were also found to develop (Text-Figs. 18–20). The development of the embryo-sac conforms to the Polygonum type (Text-Figs. 22–24).

The synergids are hooked and show filiform apparatus (Text-Figs. 24, 25). They show variable positions of nucleus and vacuole (Text-Figs. 24, 25, 36). Only very rarely was the condition normal. Mostly

TEXT-FIGS. 38–47

TEXT-FIGS. 38–47. Figs. 38–40. Development of endosperm, × 1,500. Fig. 41. Zygote, × 1,500. Figs. 42, 46 and 47. Vesicles containing free nuclei, × 1,500. Figs. 43–45. Vesicle and free nuclear endosperm, × 1,500. Fig. 45. Free nuclear endosperm and vesicle, × 950.

(*fe*, vescicle containing free nuclei.)

the synergids simulate egg. They degenerate soon after fertilization. However, in a number of cases they were observed to persist (Text-Figs. 36, 67). The egg is flask-shaped and suspended between the synergids. The polar nuclei meet in the middle of the embryo-sac, move up and fuse before fertilization to form a secondary nucleus (Text-Figs. 24, 25, 28). In a number of preparations, however, we have observed the polar nuclei in association and the male gamete attached to them (Text-Fig. 29). The antipodals degenerate before fertilization. Plenty of starch grains are present in the embryo-sac at the time of fertilization. They diminish in amount during post-fertilization stages.

The expectation raised by the occurrence of supernumerary megaspore mother cells and megaspores has been fulfilled. Many cases of twin embryo-sacs and triplets have been observed (Text-Fig. 75). Text-Fig. 74 shows a twin embryo-sac with abnormal organization. In the lower sac there are thirteen nuclei while the upper has only two prominent nuclei.

Text-Figure 26 *a*, *b* shows an eight-nucleate abnormal embryo-sac. In this the egg apparatus consists of four cells instead of the usual three. Two of the cells are egg-like.

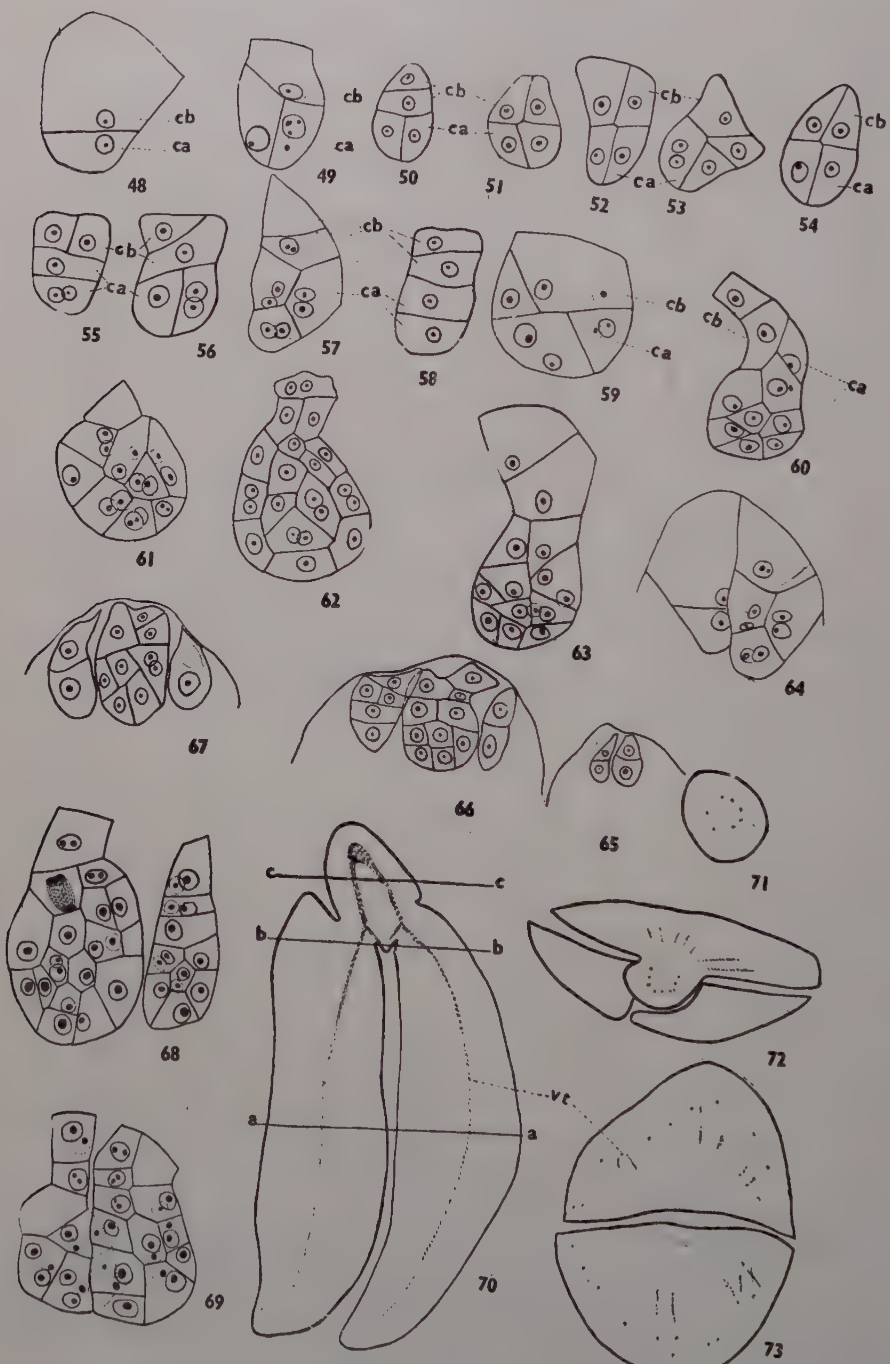
FERTILIZATION

The entomophilous flowers are protandrous and therefore cross-pollination seems to be the rule. Germinating pollen grains on the glandular stigma show monosiphonous condition. The pollen tube traverses through the stylar canal and enters the ovule through the micropyle. One of the synergids is destroyed in the process of fertilization (Text-Fig. 27). But in a few fertilized embryo-sacs both the synergids were intact (Text-Figs. 28, 36). The pollen tube may persist for sometime after fertilization (Text-Fig. 36). Persistent pollen tubes are also known in other members of the family (Nair, 1956 *b*, 1958, 1959 *a*, *b*). Dark staining X-bodies were often found at the discharged end of the pollen tube (Text-Fig. 28).

Syngamy and triple fusion have been observed in a number of cases (Text-Figs. 28–30). Syngamy precedes triple fusion.

ENDOSPERM

Soon after fertilization the embryo-sac elongates considerably. The division of the primary endosperm nucleus is much earlier than the zygote. The endosperm is of the free nuclear type. A large number of free nuclei are formed by repeated synchronous divisions



TEXT-FIGS. 48–73.

TEXT-FIGS. 48-73. Figs. 48–63. Development of embryo, × 1,500. Figs. 64, 65 and 67–69. Twin embryos, × 1,500. Fig. 66. A triplet of embryos, × 1,500. Fig. 70. L.S. Mature embryo, × 100. Figs. 71–73. T.S. embryo at levels marked *aa*, *bb*, and *cc* in Fig. 70. × 100.

(*ca*, terminal cell; *cb*, basal cell; *vt*, vascular tissue.)

(Text-Figs. 31, 37). There is a marked chalazal aggregation of the nuclei as in other members of the family. Some of the nuclei get aggregated into small groups in the middle part of the embryo-sac. Their cytoplasm is distinct from the general cytoplasm and this makes them appear as nodular masses of endosperm (Text-Figs. 33–35, 37). The endosperm nodules show a wide variety of shape and size. Nodules have been observed in a number of cases. They often show nuclei of different sizes (Text-Fig. 35). In one case there was a very large nucleus being surrounded by seven smaller dividing nuclei (Text-Fig. 34). The number of nuclei in a nodule varies from two to sixteen. Sometimes the endosperm nodules were enuclear (Text-Figs. 32, 37).

In the region of the egg apparatus of some of the embryo-sacs, vesicles containing free nuclei have been observed. They have well-defined walls, are full of starch grains, and the nuclei stain differently from those of the endosperm nuclei (Text-Figs. 42–47). The number of nuclei in the vesicle varies from two to many. Embryo-sacs showing these vesicles did not show any trace of zygote or proembryo. The origin and ultimate fate of these vesicles could not be understood fully. The nature and position of these vesicles suggest that they might have been formed from one of the cells constituting the egg apparatus.

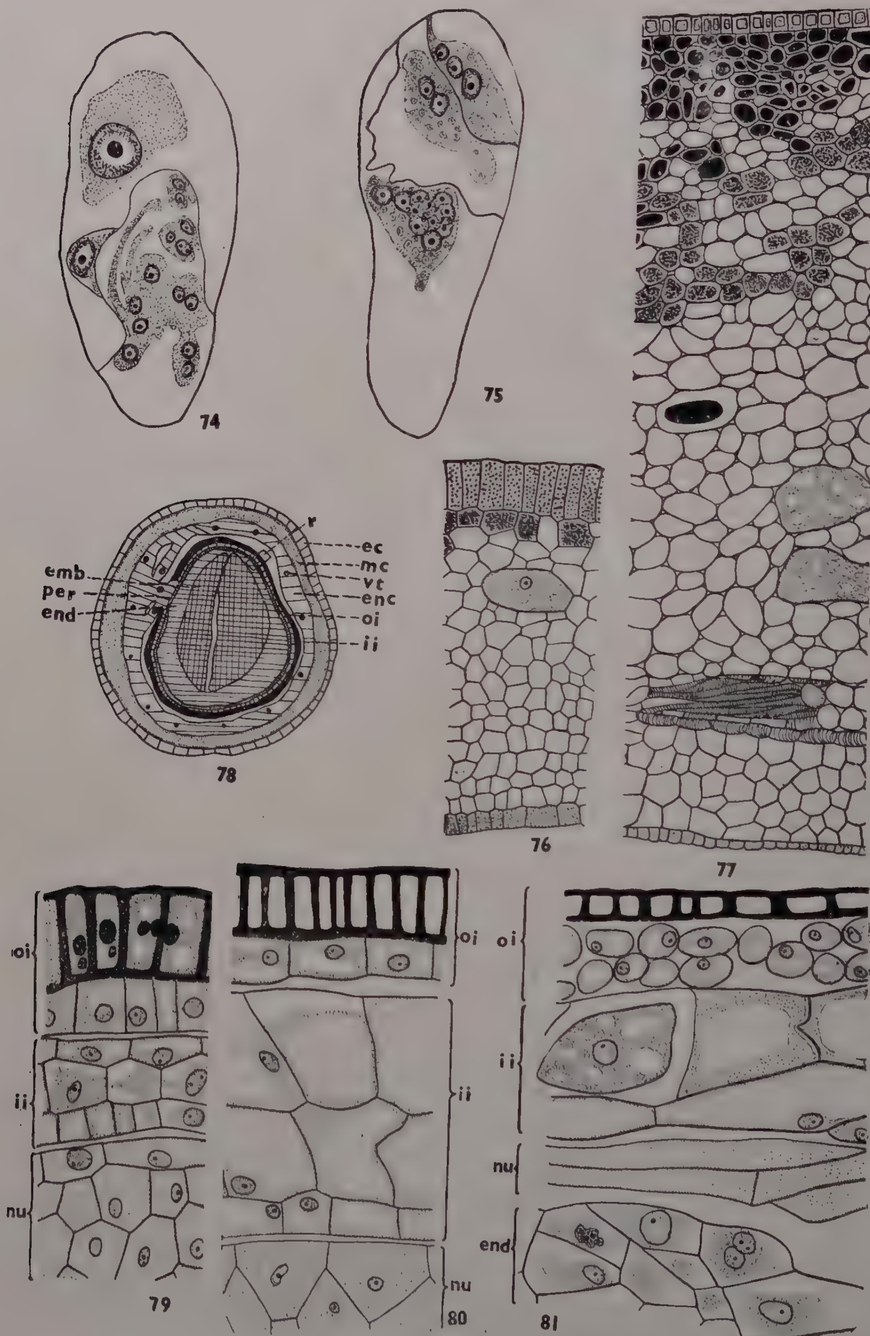
Wall formation in the endosperm begins very late and is centripetal (Text-Fig. 38). The cells of the endosperm are mostly uninucleate but sometimes binucleate cells have also been observed (Text-Fig. 39). The nuclei of the peripheral endosperm cells were often found to be lobed and contain many nucleoli (Text-Fig. 40). The growing embryo consumes most of the endosperm and in a mature seed there are only three to five layers of cells. The cells of endosperm are thin-walled. At maturity they are filled with reserve food material, chiefly oil. The cells surrounding the embryo have distorted appearance.

EMBRYO

The zygote (Text-Fig. 41) enlarges considerably and begins to divide after a large number of free endosperm nuclei have been formed. The first division is transverse producing a terminal cell *ca* and a basal cell *cb* (Text-Fig. 48). Rarely the division may be by an oblique transverse wall (Text-Fig. 49). The sequence of divisions after the two-celled proembryo is extremely variable:

(*a*) The terminal cell and the basal cell divide by vertical or an oblique vertical wall (Text-Figs. 51–54).

(*b*) The basal cell divides by a vertical wall and the terminal cell by a transverse wall (Text-Fig. 55).



TEXT-FIGS. 74–81

TEXT-FIGS. 74–81. Figs. 75–76. Twin and triplet embryo-sacs, × 1,500. Figs. 76-77. T.S. fruit wall just after fertilization and heart-shaped stage of embryo respectively, × 750. Fig. 78. T.S. of a mature fruit (diagrammatic), × 50. Figs. 79–81. Stages in the development of seed-coat, × 1,500. Fig. 81. Portion marked *r* in Fig. 78 magnified.

(*ec*, epicarp; *emb*, embryo; *enc*, endocarp; *end*, endosperm; *ii*, inner integument; *mc*, mesocarp; *nu*, nucellus, *oi*, outer integument; *per*, perisperm.)

(*c*) The terminal cell divides by an oblique vertical wall and the basal cell by an oblique transverse or a transverse wall (Text-Figs. 50, 56).

(*d*) The terminal cell and the basal cell undergo transverse divisions producing a filament of four cells (Text-Fig. 58).

Further divisions are very variable (Text-Figs. 57, 59–63) and therefore it was not possible to trace the sequence of development of the embryo. The mature embryo is dicotyledonous and both the cotyledons are almost similar. The embryo is fairly large and has well-defined vascular tissue in the hypocotyle region and extending into the cotyledons (Text-Figs. 70–73). Some of the cells in the cotyledons are secretory.

POLYEMBRYONY

Garudamma (1956) could not trace the origin of an additional embryo she has observed. In the present study several cases of twin embryos have been observed in various stages of development (Text-Figs. 64, 65, 67–69). One of them is zygotic in origin and the other is developed from one of the synergids. The occurrence of persistent synergid by the side of the zygote, although not a regular feature, is frequent. This persistent synergid has the nucleus in the basal region. In most cases the synergid undergoes a transverse division, almost simultaneously, with the zygote (Text-Figs. 65). However the zygotic embryo seems to develop faster than the other. Rarely both the embryos were equally developed. The twin embryos may be closely juxtaposed or superposed.

Text-Figure 67 shows an embryo-sac with two persisting synergids. One of them is two-celled while the nucleus of the other has not divided. In one ovule there were two synergid embryos on either side of the zygotic embryo. One of them was five-celled and the other was two-celled (Text-Fig. 66).

SEED

When the embryo-sac is ready for fertilization there are four to six layers and ten to twelve layers of nucellar cells on the sides and the chalazal end respectively. During post-fertilization stages the nucellar cells are consumed by the growing endosperm and in a mature seed only two or three layers of cells are present in the periphery (Text-Fig. 81).

Both the integuments contribute towards the formation of seed-coat (Text-Figs. 79–81). In a mature seed the outer seed-coat consists of a thick-walled epidermis and three layers of loosely arranged cells

(Text-Fig. 81). The cells of the inner integument undergo tangential elongation and become the inner seed-coat.

Pericarp

During maturation the wall of the fruit undergoes considerable changes. At the time of fertilization the ovary wall is composed of ten to twelve layers of mesophyll cells between the epidermis (Text-Fig. 76). After fertilization the mesophyll cells divide rapidly and produce 35–38 layers of parenchymatous cells (Text-Fig. 77).

The fruit is a drupe. Six to eight layers of cells constituting the epicarp in the mature fruit contain taninn. The walls of the innermost eight to nine layers of cells get thickened and form the endocarp. Gradually intercellualr spaces appear between the cells in between the epicarp and the endocarp. Finally their walls break down and form the mucilagenous pulpy mesocarp (Text-Fig. 78).

Discussion

Garudamma (1957) writes that in each locule of the ovary there are two to four ovules on an axile placenta. In none of the large number of flowers we have examined the number of ovules exceeded two per locule (*see also* Hooker, 1875). As shown earlier (Nair, 1956 *a*) the placentation in *Azadirachta* is parietal.

According to Wiger (1935) the development of endosperm in some members of Meliaceae is independent of fertilization and triple fusion. In *Azadirachta* triple fusion has been observed in a considerable number of cases. The endosperm is formed by the division of triple fusion nucleus as is also the case in *Sandoricum indicum*, *Naregamia alata*, *Melia azedarach*, *Cedrela toona* and *C. serrata* (Nair, 1958, 1959 *a b*, *c*).

An interesting feature of the endosperm development is the presence of nodules. Endosperm nodules are reported in *Impatiens roylei* (Dahlgren, 1934), *Musa errans* (Juliano and Alcala, 1933), *Oldenlandia corymbosa* (Farooq, 1953), *Pennisetum typhoideum* (Narayanaswami, 1953), *Stackhousia linariaefolia* (Narang, 1953), *Cyclanthera explodens*, *Heterospermum candigerum*, *Sechium edule*, *Luffa acutangula*, *Coriandrum sativum* (Singh, 1955; Singh and Gupta, 1956), etc. Endosperm nodules may be a common occurrence in angiosperms.

Garudamma (1956) writes that the development of embryo in *Azadirachta indica* falls in the fifth group belonging to the third megarch type of the first period in the system of embryogenic classification of Souèges (1939). Our observations on the embryo development show that there is no strict sequence in the division as described by Garudamma (1956). The zygote divides by a transverse wall or an oblique transverse wall. Further sequence of division in the proembryo is very variable so that it is not possible to place it in any definite type.

Only a single pollen tube has been observed in embryo-sacs having twin embryos and therefore the synergids do not seem to get fertilized. In all probability the synergid embryo is haploid. However no chromosome count could be made, to confirm this.

Summary

There are two to three rows of sporogenous cells in a longitudinal section of the anther. Microsporogenesis proceeds in the usual way. The cells of the glandular tapetum are two-nucleate. Pollen grains are shed at the three-celled stage. The number of germinal furrows varies from three to nine, the frequent condition being tetraporate. A few cases of polyspory has been observed.

A many-celled hypodermal archesporium is distinguished in the bitegmic crassinucellate and anatropous ovule. Generally only one cell develops further. The development of the embryo-sac conforms to the Polygonum type. The antipodals degenerate before fertilization. Twin embryo-sacs and triplets have been observed.

Fertilization is porogamous. Syngamy and triple fusion have been observed in several cases.

The division of the primary endosperm nucleus is earlier than the zygote. The endosperm is free nuclear. It later becomes cellular. In the mature seed only three to five layers of endosperm cells are present. Several cases of endosperm nodules have been observed. Vesicles containing variable number of nuclei have been observed in the micropylar end of the embryo-sacs.

The zygote divides by a transverse wall or an oblique transverse wall. Further divisions are very irregular. The mature embryo is dicotyledonous.

Several cases of polyembryony have been observed. The additional embryo is developed from the synergid.

A single seed develops in each ovary. Two to three layers of nucellar cells persist in the seed as perisperm. Both the integuments contribute towards the formation of the seed-coat. The outer seed-coat consists of a thick-walled epidermis and three layers of loosely arranged cells. The inner seed-coat is two to three layered. The fruit is a drupe.

In conclusion we tender our grateful thanks to Dr. B. N. Mulay for encouragement, suggestions and facilities.

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THE EFFECT OF THE BLACK TIP DISEASE ON THE ASCORBIC ACID CONTENT OF THE MANGO FRUIT

By S. C. Agarwala, C. P. Sharma and Ashok Kumar

Department of Botany, Lucknow University, Lucknow

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Introduction

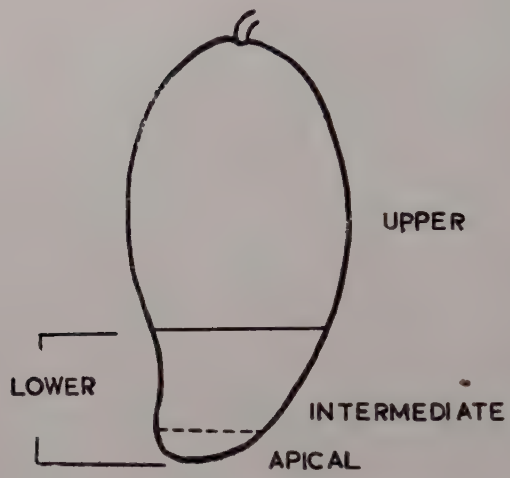
A constituent of the brick kiln fumes has been shown to cause a necrosis of the distal part of the fruit in a wide variety of mangoes grown in Uttar Pradesh and Bihar (Das-Gupta *et al.*, 1950). This disease described as the 'black tip' (necrosis) disease (Das-Gupta and Verma. 1939) is known to cause appreciable changes, particularly in the distal part of the fruit, in total titrable acids, total sugars, fructose and starch (Das-Gupta and Agarwala, 1947). Further studies were made to find out the effect of the black tip disease on the mineral composition, certain enzyme systems and the ascorbic acid content of the mango fruit.

This paper describes the effect of the black tip disease on the ascorbic acid content in mango fruits of two economically important varieties, showing a high incidence of disease in mango orchards near Lucknow. In some selected samples the ratio of dehydroascorbic acid to ascorbic acid was also determined.

Material and Methods

Sampling.—Healthy and diseased fruits of approximately the same age, seven to eight weeks after fruit set, of the Malihabadi safeda and tamboori varieties were collected from mango orchards at Bahadurpur and Ghazipur respectively. For each variety the undermentioned types of fruits were collected: (i) healthy fruits from trees bearing healthy fruits only (type HI), (ii) healthy fruits from trees bearing both healthy and necrotic fruits (type HII), (iii) diseased fruits showing necrosis of the extreme distal end of the fruit (type NI), and (iv) diseased fruits showing an advanced stage of the disease, necrosis spread to more than one-half of the distal one-third part of the fruit (type NII). Nine to twelve fruits were included in each of the three replicates for each type of fruits.

Each fruit was divided into three parts, *viz.*, upper, intermediate and apical (Text-Fig. 1). The upper part comprised the proximal two-third length of the fruit. The apical included the diseased part of the diseased fruit or the corresponding length of the healthy fruits. The intermediate included the parts other than the upper and the apical. The endocarp and the seed were not included in the analysis. The



Text-Fig. 1. The mango fruit. The upper comprised the proximal $\frac{2}{3}$ length and intermediate and apical together the lower $\frac{1}{3}$ length of the fruit. The apical was the diseased or its corresponding part.

corresponding parts of each type of fruits were chopped, bulked and mixed. From this a suitable weight of the tissue was drawn for the determination of ascorbic acid. The estimation of interfering substances, reductones and allied substances, was made on the apical part of the healthy and the necrotic mangoes of the two varieties. Dehydroascorbic acid determinations were made on the upper and the apical parts of the healthy and the diseased fruits. All estimations were made in triplicate. As far as possible the results of analysis have been statistically analysed and tested for significance at the 5% probability level.

Analytical.—Samples awaiting analysis were stored at a temperature of 0 to 5° C. Extracts for the ascorbic acid determinations were made by the method of Huelin (1949). The chilled tissue was ground with pure silica sand in sodium acetate-oxalic acid buffer, pH 1·2, in the ratio of 1 g. fruit material to 10 ml. of the buffer. The temperature during grinding was not allowed to rise above 5° C. The extracts were filtered and ascorbic acid concentration was estimated by rapid titration with 2, 6-dichlorophenol-indophenol (Harris and Ray, 1933).

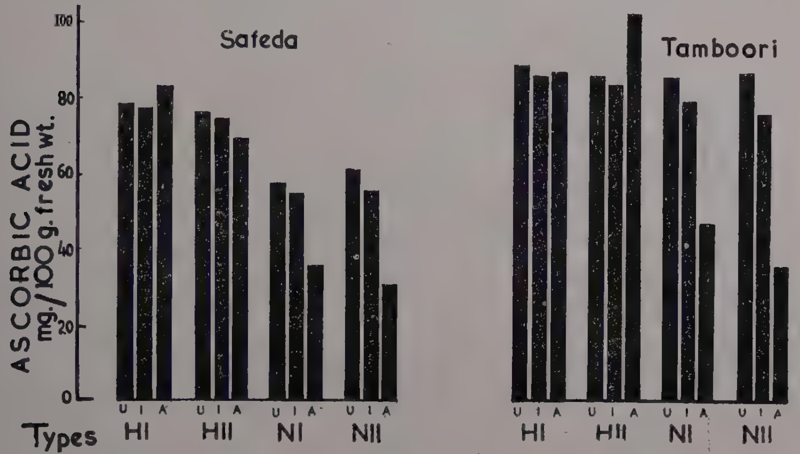
Reductones and allied substances were differentiated from true ascorbic acid by the method of Mapson (1943).

Dehydroascorbic acid was determined by the method of Huelin (1949).

Pyrex-glass distilled water and A.R. grade chemicals were used throughout. The extracts were stored in dark at 0 to 5° C, before analysis.

Results

Ascorbic acid.—The effect of the black tip disease on the ascorbic acid content of mango fruits is shown in Text-Fig. 2. In none of the



Text-Fig. 2. The effect of 'black tip' disease on the ascorbic acid content of the mango fruit. Letters U, I and A denote the upper, intermediate and the apical parts of the fruits respectively; letters HI, HII, NI and NII represent the four types of fruits, healthy fruits from trees bearing healthy fruits only (type HI), healthy fruits from trees bearing both healthy and necrotic fruits (type HII), diseased fruits showing necrosis of the extreme distal end of the fruit (type NI), and diseased fruits showing an advanced stage of the disease, necrosis spread to more than one-half of the distal one-third part of the fruit (type NII).

varieties studied there was any appreciable or significant difference in the ascorbic acid content in the different parts of the healthy fruits, collected from either trees bearing healthy fruits only or trees bearing both healthy and necrotic fruits.

The difference in the ascorbic acid content of the corresponding parts of the HI and HII types of safeda and tamboori fruits were also not significant.

In both varieties of mango, the ascorbic acid content in the apical part of the necrotic fruits, of both types NI and NII, was markedly and significantly lower than in the corresponding part of the healthy fruits, types HI and HII. Compared to the upper and the intermediate part the apical part of the diseased fruits had the least ascorbic acid. The ascorbic acid concentration in the upper and the intermediate part of the diseased safeda mangoes was also appreciably and significantly lower than in the corresponding parts of the healthy fruits. No such depression in the upper and intermediate regions of the diseased tamboori fruits was found.

Reductone fractions.—As no appreciable difference in the lengthwise distribution of the ascorbic acid content was found in healthy fruits,

reductones and allied substances were determined on the apical part of the healthy and the diseased fruits of the two varieties.

The sodium acetate-oxalic acid extracts of the healthy and the diseased mango fruits did not show any change in the 2, 6-dichlorophenol-indophenol titre on keeping in dark at 20° C. for three hours. This would, as demonstrated by Mapson (1943), show the absence of dihydroxymaleic acid and similar reducing substances in the tissue extracts.

TABLE I

Mean values for the 2, 6-dichlorophenol-indophenol titrable, interfering substances in the sodium acetate-oxalic acid extracts of healthy and necrotic mangoes

Variety and type of fruit	Ascorbic acid		Interfering substances		
	By indophenol titration	Corrected for total interfering substances	Cysteine, sulphite type	Reductone type	Total
	mg./100 g. Fresh weight		mg./100 g. Fresh weight as AA		
Safeda HI ..	83·3	70·0	8·3	5·0	13·3
Safeda NII ..	30·9	19·0	5·9	6·0	11·9
Tamboori HI ..	100·0	92·0	0·0	8·0	8·0
Tamboori NII ..	35·5	26·5	0·5	8·5	9·0

Cysteine, sulphite type of interfering substances were found in the safeda variety only. The reductone type of reducing substances were present in both the varieties. The concentration of the reducing substances other than ascorbic acid, as found by 2: 6 dichlorophenol-indophenol titre, was not affected by the black tip disease in either of the two varieties. It is also evident from Table I that in the apical part of the diseased fruits the total reducing substances other than ascorbic acid accounted for a good part of 2, 6-dichlorophenol-indophenol titre.

Dehydroascorbic acid.—Estimations for dehydroascorbic acid were made on a fresh set of samples.

In healthy fruits, the dehydroascorbic acid comprised about 15% of the total ascorbic acid in the safeda variety and 30% of the total ascorbic acid in the tamboori variety. In both the varieties, the concentration

TABLE II

Mean values for the total ascorbic acid and the DHA/AA ratios in the healthy and necrotic mangoes

Variety and type of fruit	Portion of fruit: Upper				Portion of fruit: Apical			
	AA	DHA	AA+DHA	DHA/AA ratio	AA	DHA	AA+DHA	DHA/AA ratio
	mg./100 g. Fresh weight				mg./100 g. Fresh weight			
Safeda HI ..	74·0	14·0	88·0	0·19	108·0	20·0	128·0	0·19
Safeda NII ..	84·0	17·0	101·0	0·19	24·0	46·0	70·0	1·92
Tamboori HI ..	93·0	40·0	133·0	0·43	100·0	48·0	148·0	0·44
Tamboori NII ..	80·0	39·0	119·0	0·49	28·0	47·0	75·0	1·68

of DHA in the apical part of the healthy fruits was slightly higher than in the upper part. Unlike the ascorbic acid, in none of the varieties dehydroascorbic acid was depressed by black tip disease; on the other hand, in the diseased part of the safeda variety an increase was found.

In both varieties, the apical part of the diseased fruits showed a very high dehydroascorbic acid to ascorbic acid ratio. In the case of safeda variety the DHA/AA ratio in the apical part of the diseased fruits was about ten times higher than in the corresponding part in the healthy fruits or in the upper part of the same type of fruits. Similar trend was shown by the tamboori variety of mangoes. DHA/AA ratio in the apical part of the fruits in this variety was four times as high as in the upper part of the same type of fruits or the upper corresponding part in the healthy fruits.

Total ascorbic acid.—The effect of the black tip disease on the total ascorbic acid (AA + DHA) content of both safeda and tamboori mangoes was appreciable. In both the varieties the total AA content of the apical (diseased) part of the diseased fruits was markedly lower than in the upper part of the same type of fruits or in the corresponding part of the healthy fruits.

DISCUSSION

The safeda and tamboori varieties of mango fruits were found to be rich in ascorbic acid as some other varieties described by a number of workers (Mustard, 1945; Bhutani, 1946; Munsell, 1946; Spencer *et al.*, 1956). As reported for certain Florida grown varieties of mango by Mustard and Lynch (1945), healthy fruits of our varieties did not show appreciable differences in the ascorbic acid content of the fruits in the longitudinal direction.

The black tip disease caused a marked and significant overall decrease in the ascorbic acid content of the fruits of both safeda and tamboori varieties. The decrease in the ascorbic acid due to the black tip disease was very marked and highly significant ($P = 0 \cdot 01$) in the diseased (necrotic) part of the fruits. The decrease in the ascorbic acid content in the diseased tissue would become more pronounced on the exclusion of other reducing substances which comprise over 25% of the ascorbic acid value, as determined by the 2, 6-dichlorophenol-indophenol titrations.

In both the varieties, particularly in the tamboori, the dehydro-ascorbic acid (DHA) was found to be appreciably high.

In the tamboori variety the DHA concentration was not appreciably affected by the black tip disease and like ascorbic acid total AA in the apical (diseased) part of the diseased fruits was markedly depressed. In the safeda variety, the apical (diseased) part of the diseased fruits showed an increase in the DHA over the upper part of the same type of fruits or the corresponding part of the healthy fruits. However, in spite of higher DHA concentration, the total AA in the apical (diseased) part of the diseased safeda fruits was markedly low. The ratio of DHA to AA in the diseased part of the fruits of the two varieties was very high and would suggest that in the diseased tissue compared to the healthy tissue the systems which oxidise AA are more powerful than those which reduce it.

While, in view of the findings of Barker and Mapson (1959), it would be desirable to find out percentage of DHA in mango fruits which arose by oxidation of AA during our extraction conditions, it would seem highly improbable that the higher DHA/AA ratio in the diseased tissue compared to normal tissue was an artifact. The latter could be true if during extraction procedure the system of oxidation of AA in the diseased tissue was more powerful than in the healthy tissue, and further that *in vivo* such a system was not operating in this manner.

As there was in the diseased tissue a marked depression in AA without a corresponding increase in DHA, it would appear that in diseased tissue part of the AA was being destroyed at higher rate than in the healthy tissue. Mapson (1958) has pointed the possibility of AA being oxidised to DHA and then irreversibly converted to 2, 3-diketogulonic acid *in vivo*. It may well be that such a mechanism is operative in mango fruits, and is more active in the diseased tissue.

Summary

The ascorbic acid content of the different parts of the mango fruits of safeda and tamboori varieties, in relation to the black tip disease, has been described.

The black tip disease has been shown to cause a marked and significant decrease in the ascorbic acid content, particularly in the apical (diseased) part of the diseased fruits, On differentiating the true

ascorbic acid from the other reducing substances, the effect of the disease on the ascorbic acid became more pronounced.

Both varieties have been shown to be high in dehydroascorbic acid. The DHA content of the fruits was not depressed by the black tip disease in either of the two varieties. In one variety, safeda, the diseased fruits showed an increase in the DHA in the diseased part. The total ascorbic acid, however, showed a considerable decrease in the diseased parts of the diseased fruits of both the varieties.

The DHA/AA ratio in both the varieties, particularly in the diseased parts, has been shown to be very high.

It is suggested that the depression in the ascorbic acid in the tissue of the diseased fruits is a result of an irreversible oxidation of the AA to 2, 3-diketogulonic acid *via* DHA.

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FUNGI CAUSING PLANT DISEASES AT JABALPUR (MADHYA PRADESH)—III

By G. P. Agarwal

Department of Botany, Mahakoshal Mahavidyalaya, Jabalpur

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Agarwal, Nema and Beliram (1959) and Agarwal and Beliram (1960) have described in the first two series of the paper seventy-one fungi causing plant diseases at Jabalpur and its suburbs. The present paper describes five more deuteromycetous fungi occurring at Jabalpur.

The number of the species are the serial numbers of the fungal flora of Jabalpur.

72. *Alternaria tenuis* auct. In Neergaard, P., *Danish species of Alternaria and Stemphylium* 1945: 81–129.

On leaves of *Xanthium strumarium* L. and *Ipomea reptans* Poir., Wright town, February 1957, Leg. G. P. Agarwal and R. C. Agnihotri; on leaves of *Pisum sativum* L. and *Momordica dioica* Roxb., Gadha area, December 1957, Leg. Agnihotri.

Symptoms of the Disease

The disease first appears as pale to light brown spots on the leaves. Spots increase in size, become circular to irregular, dark brown and may coalesce. Concentric zonations are formed only in *Ipomea reptans*. The infected portion later on dries up and withers away.

The Causal Organism

Conidia oval to pyriform, epispore smooth or minutely verrucose, 1–5 transverse septate, average 3 septate, longitudinal septa 1–4, $16 \cdot 4–82 \times 6 \cdot 5–13\,\mu$, average $29 \cdot 8 \times 7 \cdot 7\,\mu$, normally beakless, sometimes beaked, beak small, gradually prolonged from the spore, lighter coloured or concolorous, septate or non-septate, with a prominent apical scar showing that a chain of at least two spores must have occurred.

The four strains were identified as *Alternaria tenuis* auct. by Dr. Paul Neergaard. All the hosts are new records for *Alternaria tenuis*.

The specimens are deposited in the Botany Department, Mahakoshal Mahavidyalaya, Jabalpur.

73. *Corynespora cassiicola* (Berk. and Curt.) Wei. In *Mycol. Pap. C.M.I.* **34:** p. 5.

On leaves of *Hiptage benghalensis* Kurz., King's Garden, August to September 1959, Leg. S. K. Hasija.

Symptoms of the Disease

The disease starts on both the surfaces of the leaf as violet pinhead spots which increase in size and each develops a whitish dot-like structure in the centre. Lesions are circular to irregular. The green of the leaf around a spot becomes slightly lighter coloured. The central region of the lesions becomes ash-coloured, thin, papery and necrotic, in which appear clumps of conidiophores bearing conidia as black dots. Spots often coalesce. Midrib and the main veins are freely traversed. A leaf may show numerous spots and in severe cases the whole leaf is affected and there may be defoliation. The disease appeared in an epiphytotic form and it was difficult to locate healthy leaves in the trees.

The Causal Organism

Conidiophores olivaceous, at times paler towards the tip, simple, septate, of variable length, emerging singly or in groups of two to three, sometimes swollen at the base, swollen bases often united; conidia borne singly at the tip, faintly olivaceous, often with a hyaline isthmus at the basal end, cylindrical or obclavate, straight or curved, tapering moderately towards apex, up to 17-septate, $15 \cdot 5–158 \times 7–19 \cdot 4\,\mu$.

Hiptage benghalensis is a new host record for *Corynespora cassiicola*. It has been reported on leaves of *Croton sparsiflorus* from Patna, Bihar, by Thirumalachar and Lacy (1951) and on dead stems of *Cassia* sp. from Madras State, on rotting leaves of *Carica papaya* and on dead stems from Travancore-Cochin State by Subramanian (1952).

The species has been identified by Dr. M. B. Ellis. The material is deposited in the Herbarium of the Commonwealth Mycological Institute, Kew, No. 77915 and in the Botany Department, M.M.V., Jabalpur.

74. *Pestalotiopsis fici* Steyaert. In *Bull. Jard. bot. Brux.* **19:** 285–354, 1949.

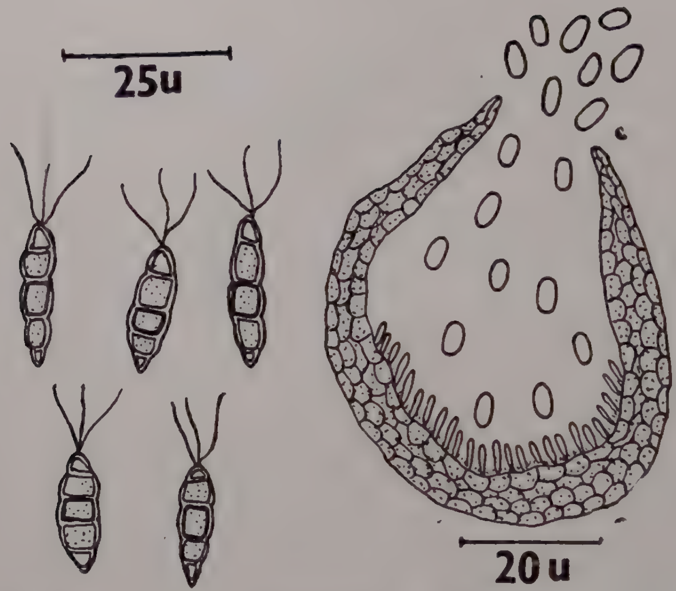
On leaves of *Ficus religiosa* L., near College Buildings, November 1958, Leg. R. Beliram.

Symptoms of the Disease

The disease first appears as small pale brown pinhead spots with a halo of yellow colour. It may start on either surface of the leaf from any part. Spots increase in size, become mostly irregular, less often circular. The central region of the lesion becomes ash-coloured with a dark brown margin and a halo of bright yellow colour. The lesions tend to avoid the midrib and the larger veins. Spots frequently coalesce and increase the diseased surface.

The Causal Organism

Acervuli subepidermal; conidia mostly 4-septate, sometimes 3-septate, central cells coloured, end cells hyaline, with 2–3 cilia at the



TEXT-FIGS. 1–2. Fig. 1. *Pestalotiopsis fici*, conidia. Fig. 2. *Phyllosticta tephrosiae*, pycnidium and conidia.

apical end and a beak at the basal end, 16–26 × 3·3–6·5 μ, average 20·4 × 4·5 μ, coloured part 9–20 μ in length, average 13·4 μ.

Pestalotiopsis fici is a new fungus record for India. *Pestalotia elasticola* P. Henn. has been reported on living leaves of *Ficus elastica* from Badamtam (Darjeeling) and on leaves of *Artocarpus integrifolia* from Pusa (Mundkur and Kheswalla, 1942; Ramkrishnan and Subramanian, 1952).

The species has been identified by Dr. Ellis. The material is deposited in the Kew Herbarium No. 76410 and in the Botany Department, M.M.V., Jabalpur.

75. *Gloeosporium artocarpi* Delacr. Saccardo, *Syll. Fung.*, 1906, **18**: 454.

On leaves of *Artocarpus integrifolia* L., Beoharbag, January 1959, Leg. Agarwal.

SYMPTOMS OF THE DISEASE

The disease may start from any part of the leaf but often from apex or the margin. The lesions are brown, irregular and may cover more than half the leaf.

THE CAUSAL ORGANISM

Mycelium septate, hyaline, inter or intracellular; acervuli only on the upper surface, immersed; conidiophores not projecting beyond

the epidermal layer, hyaline; conidia hyaline, single-celled, sometimes one septate, straight or curved, $9 \cdot 8$–$20 \times 1 \cdot 6$–$3 \cdot 3\ \mu$, average $12 \cdot 9 \times 2 \cdot 5\ \mu$.

Gloeosporium artocarpi is the conidial stage of *Glomerella artocarpi* Delacr. Ramkrishnan and Ramkrishnan (1950) first reported *Glomerella artocarpi* on living leaves of *Artocarpus integrifolia* from Thondamuthur (Coimbatore) but they also observed only conidial stage.

This is the first record of *Gloeosporium artocarpi* from Madhya Pradesh. The material is deposited in the Botany Department, M.M.V., Jabalpur.

76. ***Phyllosticta tephrosiae* Agarwal sp. nov.** On *Tephrosia purpurea* Pers., Mahakoshal Mahavidyalaya Compound, September 1959, Leg. Agarwal.

Symptoms of the Disease

The disease starts from any part of the leaf on both the surfaces. Spots are brown-coloured, circular, elongated or irregular. A single leaf may have many spots which often coalesce.

The Causal Organism

Pycnidia dark brown, globose to subglobose, immersed in host tissue, 37–109 μ in diameter, average 68 μ; conidiophores small hyaline; conidia hyaline, single-celled, oval to spherical, $3 \cdot 9$–$6 \cdot 2 \times 3$–$3 \cdot 9\ \mu$, average $5 \cdot 8 \times 3 \cdot 2\ \mu$.

The specimen was examined by Mr. Sutton, Assistant Mycologist, Commonwealth Mycological Institute, Kew. It is a new collection there. So far no *Phyllosticta* has been described on any *Tephrosia*. The fungus is presented here as a new species *Phyllosticta tephrosiae*.

Phyllosticta tephrosiae sp. nov.

Pycnidia fusce brunnea colore, globosa vel sub-globosa, immersa in textus plantae hospitis, diametientia 37–109 μ, medietate 68 μ; conidiophori minutissimi, hyalini; conidia hyalina, semel cellulata, ovalia vel sphaerica, $3 \cdot 9$–$6 \cdot 2 \times 3$–$3 \cdot 9\ \mu$, mediet. $5 \cdot 8 \times 3 \cdot 2\ \mu$.
Habitat in maculis foliorum viventium *Tephrosiae purpureae* Pers. ad Jabalpur in India, mense Septembri anni 1959, leg. G. P. Agarwal.

The type specimen has been deposited in Kew Herbarium No. 77917 and in the Botany Department, M.M.V., Jabalpur.

Summary

The present paper describes five parasitic Fungi Imperfecti occurring at Jabalpur. It includes *Alternaria tenuis* auct. on leaves of *Xanthium strumarium* L., *Ipomea reptans* Poir., *Pisum sativum* L. and *Momordica dioica* Roxb., the four new host records for *Alternaria tenuis*; *Corynespora cassiicola* (Berk. and Curt.) Wei causing leaf-spot of *Hiptage benghalensis*

Kurz., a new host record; *Pestalotiopsis fici* Steyaert on leaves of *Ficus religiosa* L., a new fungus record for India; *Gloeosporium artocarpi* Delacr. On leaves of *Artocarpus integrifolia* L., a new record for the State and *Phyllosticta tephrosiae* Agarwal, a new species on leaves of *Tephrosia purpurea* Pers.

Acknowledgment

My grateful thanks are due to Dr. J. C. F. Hopkins, Director, Dr. M. B. Ellis and Mr. Sutton, Assistant Mycologists, Commonwealth Mycological Institute, Kew, England, and Dr. Paul Neergaard of Denmark for kindly identifying the different species. Thanks are also due to Prof. U. Mukerjee, Principal, Mahakoshal Mahavidyalaya, Jabalpur, for laboratory facilities; to Mr. S. K. Hasija for technical assistance and to the University of Jabalpur for kindly sanctioning a Research Grant.

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POLLEN TYPES IN THE EPACRIDACEAE

By C. Venkata Rao

Department of Botany, Andhra University, Waltair

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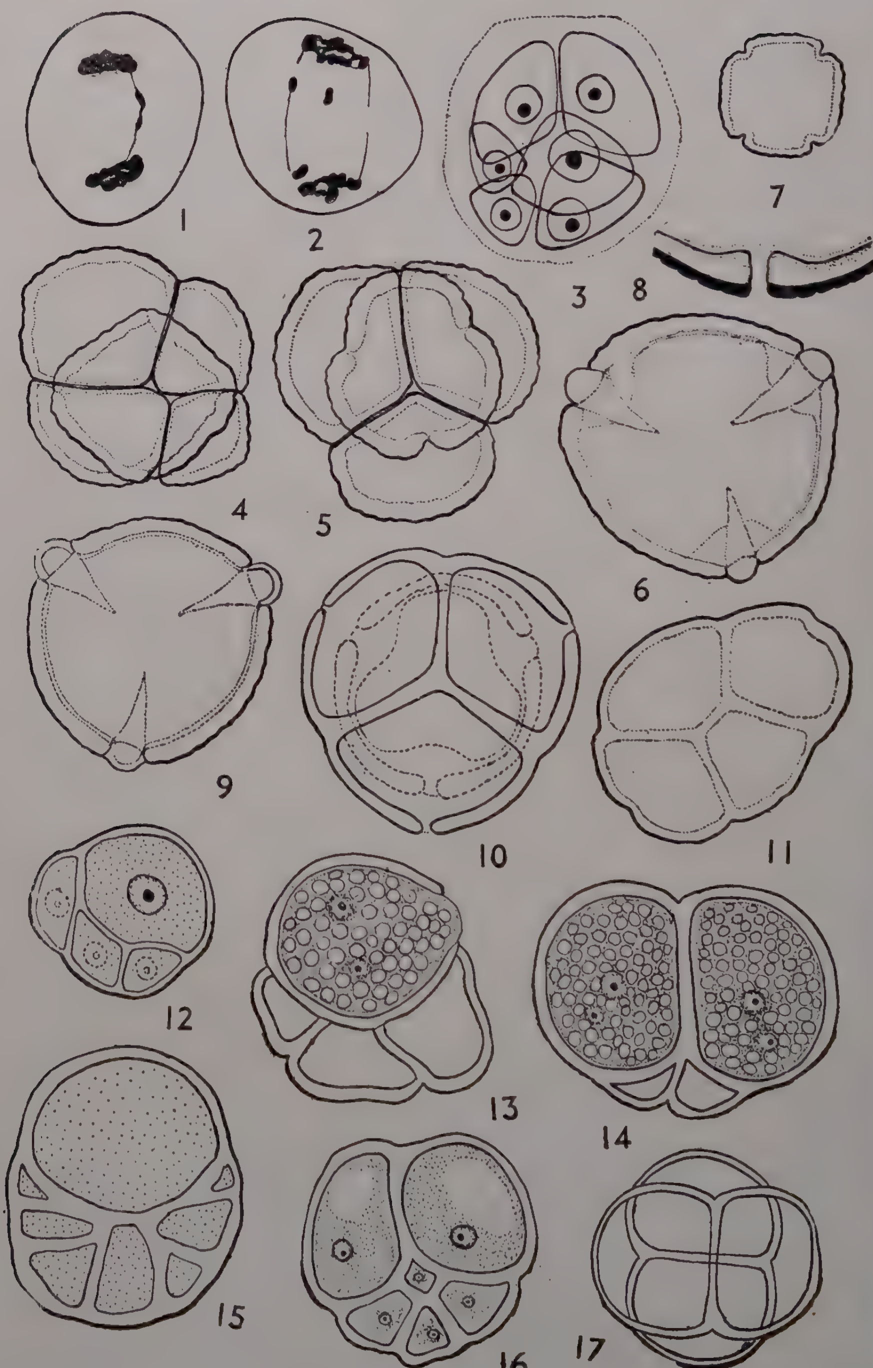
Introduction

The Epacridaceae is included by Engler and Prantl (1897) in the Ericales, the first order of the Sympetalae, along with the families Clethraceae, Pyrolaceae, Lennoaceae, Ericaceae and Diapensiaceae. Engler and Diels (1924) removed the Diapensiaceae from the order since it differs from the remaining families in not having its pollen in tetrads. Engler and Gilg (1930) divided the Ericales into two sub-orders, the Epacridineae with the single family Epacridaceae in which the anthers are 2-locular, and the Ericineae comprising the remaining families in which the anthers are 4-locular.

The Epacridaceae resembles closely the Ericaceae even in the heath-like habit. The family comprises 30 genera and about 400 species of which 26 genera and more than 320 species are Australian. A few genera are found in New Zealand, New Caledonia and Malaya. One species of *Styphelia* is found in India (Rendle, 1952) and the monotypic *Lebetanthus* in Feugia and Patagonia (South America). Bentham (1869) divided the Epacridaceae into two tribes, the Epacrideae and the Styphelieae. Drude (in Engler and Prantl, 1897) removed *Lebetanthus* and the monotypic Tasmanian *Prionotes* from the Epacrideae and constituted them into a third tribe. The present author, however, showed that there is not enough justification for the removal of *Prionotes* from the Epacrideae (Venkata Rao, 1959).

Previous Work

Though in some eurypalynous families like Acanthaceae and Compositeae there is much variation in the external features of the pollen grains, the grains are always single and their ontogeny is similar. The Epacridaceae is unique in showing a variety of pollen types which are unparalleled by any other angiospermous family. The earlier taxonomic accounts do not mention anything about the interesting pollen types. Smith-White (1948, 1955, 1955 *a*) made detailed cytological and palynological studies in the family and recognised four distinct types of pollen. However, he did not encounter any single grains and remarked: "It is probable that true single grains do not occur in the family" (Smith-White, 1955 *a*). In view of this statement, the single grains mentioned by Willis (1948) and Rendle (1952) probably refer to the monads found in several genera of the Styphelieae. The 'single grain' of *Leucopogon virgatus* sketched by Copeland (1954, Fig. 48) is also a monad as the



TEXT-FIGS. 1-17

TEXT-FIGS. 1–17. Pollen types in Epacridaceae. Figs. 1–6. *Richea sprengelioides*. Figs. 1 and 2. Formation of chromosome fragments and laggards, × 1,330. Fig. 3. A polyad, × 1,330. Figs. 4–6. Developing and mature pollen grains, × 1,000. Fig. 7. A 4-porate grain of *R. procera*, × 835. Fig. 8. Section through germ pore of *R. procera*, × 1,665. Fig. 9. A single grain of *R. milligani*, × 1,330. Fig. 10. A pollen tetrad of *Epacris lanuginosa*, × 665. Fig. 11. A bilateral tetrad of *Proiontes cerinthoids*, × 1,000. Figs. 12–16. Pollen of *C. dealbata*, × 665. Fig. 17. A tetrad of *Pentachondra pumila*, × 665.

studies of Smith-White (1955 *a*) and the present author show. Erdtman (1952) classified the pollen in the family into two types, the isodynamosporous (all spores of the same size, *i.e.*, full tetrads) and heterodynamosporous (all spores not of the same size, *i.e.*, monads, dyads and triads), and described the external features of pollen in *Epacris microphylla* and *Leucopogon amplexifolius*.

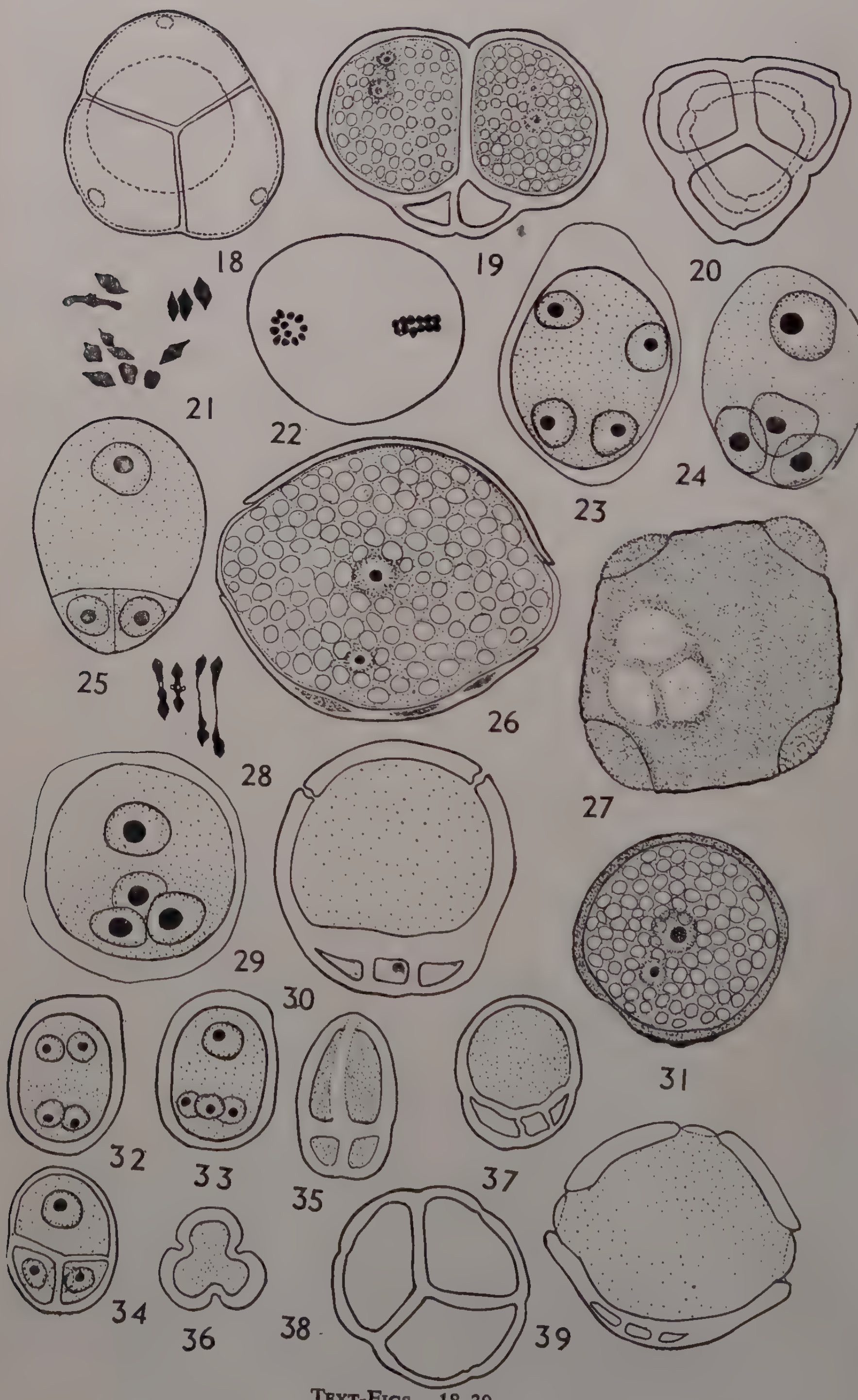
Though pollen has attracted the attention of scientific men from early times, detailed palynological studies have gained importance only recently due to their application in medicine, agriculture and stratigraphical correlation, etc. Wodehouse (1935, 1936) traced the evolutionary tendencies in pollen grains based on intensive study of their external features. However, the ontogeny of male gametophyte in angiosperms follows a remarkably uniform pattern and till recently the Cyperaceae, in which three of the microspores of a tetrad degenerate regularly, is considered as the only notable exception. There is therefore practically no literature on the evolution of pollen based on the ontogenetic studies. The present studies have brought to light two more types of pollen development in the Epacridaceae in addition to the four types already recognised by Smith-White. These are described in the following pages and the probable lines of evolution in them are suggested.

Materials and Methods

During his stay in and tour of Tasmania and Australia (1955–57) the author collected herbarium and fixed material of some Epacridaceae (listed in Table I). Of these, *Conostephium pendulum*, *Lysinema ciliatum* and *Astroloma pallidum* are from West Australia and the rest from Tasmania. Some cytological studies were made at the Department of Botany, University of Tasmania, Hobart and the work was completed at the Botany Department of the Andhra University, Waltair. Studies in cytology and early stages of pollen development were made from aceto-lacmoid smears of pollen mother cells. Mature pollen was studied from mounts in methyl green glycerine jelly and microtome sections of flower-buds stained in Delafield's haematoxylin.

Observations

Single grains.—Though Smith-White (1955 *a*) reported tetrad type of pollen in *Richea sprengelioides*, the author found that it shows single grains. In addition, two more species of the genus, *viz.*, *R. procera* and *R. milligani*, also show single grains while the remaining four species of the genus examined show tetrads. Meiotic divisions



TEXT-FIGS. 18–39

TEXT-FIGS. 18–39. Pollen types in the Epacridaceae. Figs. 18–20. A young tetrad, mature dyad and nullad of *Pentachondra involucrata*. Fig. 18. × 1,330, Figs. 19 and 20, × 665. Figs. 21–27. *Astroloma humifusum*. Figs. 21 and 22. Metaphase I and anaphase II in p.m.c., × 1,330. Figs. 23–25. Development of pollen tetrad, × 1,330. Fig. 26. A monad in section, × 300. Fig. 27. Surface view of 4-porate grain; note the degenerating microspores, × 300. Figs. 28–31. *Styphelia adscendens*. Fig. 28. Metaphase I, × 1,330. Figs. 29 and 30. Development of pollen tetrad, × 1,000. Fig. 31. A mature monad, × 250. Figs. 32–34. Development of tetrad in *Monotoca linifolia*, × 1,330. Figs. 35–37. *M. empetrifolia*. Figs. 35 and 36. Surface view and T.S. of developing tetrad, × 835. Fig. 37. A mature monad, × 835. Fig. 38. A developing monad of *Leucopogon collinus*, × 1,000. Fig. 39. A nearly mature monad of *Leucopogon ericoides*, × 1,000.

were followed in *R. sprengelioides* ($n = 13$). During anaphase I some laggards, chromosome bridges and fragments are noticed (Text-Figs. 1 and 2), which show that the species is a structural hybrid for some inversions. The fragments (and probably laggards) form micronuclei and supernumerary microspores (Text-Figs. 3 and 4). The microspores adhere together loosely for some time and finally separate out and mature into individual grains. The microspores which receive full haploid chromosome complement develop into viable grains while those which are deficient in the haploid set and those formed by the micronuclei become sterile and empty.

Mature pollen grains are spherical and tricolporate (Text-Figs. 6 and 9). Occasionally 4-porate grains are met with (Text-Fig. 7). The colpi are fusiform and have rounded pores at the middle. The exine shows fine or coarse reticulation in surface view. The sexine is relatively thinner than the nexine. The portion of the exine forming the ora is slightly thicker (Text-Fig. 8). Pollen grains are shed in the 2-celled condition. The cytoplasm of the vegetative cell accumulates abundance of starch. Dehiscence of the anther is brought about by fibrous thickenings which develop in the epidermal cells.

T-type or the full tetrad type.—Full tetrad type of pollen is seen in four species of *Richea* examined, all genera of Epacrideae and some species of the following genera of Styphelieae: *Pentachondra*, *Cyathodes*, *Lissanthe*, *Trochocarpa* and *Acrotriche*. The microspores are usually arranged in tetrahedral manner (Text-Fig. 10), though bilateral and decussate arrangements are also met with occasionally (Text-Figs. 11 and 17). The tetrads range from deeply lobed (*e.g.*, *Richea gunnii*) to nearly spherical condition as in *Epacris virgata* and *Lysinema ciliatum*. The individual grains of the tetrad are tricolporate and show fusiform colpi. The exine is finely or coarsely reticulate or rarely papillate. Sometimes one or more grains of a tetrad become sterile. The pollen of *Cyathodes parvifolia* is not of the S-type as described by Smith-White (1955 *a*) but of the tetrad type in which respect it resembles other species of the genus examined except *C. dealbata* which is described below separately.

It is interesting to notice that in Ericaceae also the majority of members show the full tetrad type of pollen. However, single grains

are also found in a few members (Oldfield, 1959). There is close resemblance in the external features of the pollen in Ericaceae and Epacridaceae.

A-type or Astroloma *type.*—Smith-White found this type first in *Astroloma* sp. but as he remarked, it is neither confined to nor characteristic of the genus. In this type, the four microspore nuclei resultant of meiotic divisions become quadrately arranged and are cut off by cell-walls. Though the four microspores are similar to start with a variable number of them degenerate during development and mature tetrads contain usually 1–3 viable grains. Rarely all the four may be fertile or all sterile (nullads). In *Astroloma conostephioides* and *A. pinifolius*, Smith-White found this type associated with irregularities in meiotic divisions. The present author found A-type in *Cyathodes dealbata* in which also the meiotic divisions proceed in an irregular manner. The fragments and laggards form supernumerary microspores as in *Richea sprengelioides.* However, the microspores do not separate out but remain permanently united so that polyads are of common occurrence. Mature pollen shows 1–3 or rarely four fertile microspores (Text-Figs. 12–16).

P-type or Pentachondra-*type.*—The present author found this type in *Pentachondra involucrata* and therefore named it P-type. In other species of *Pentachondra*, *viz.*, *P. pumila* the pollen is of the tetrad type. In *P. involucrata* ($n=13$) the meiotic divisions proceed normally and the pollen starts development as tetrads of similar microspores (Text-Fig. 18). During development two microspores of each tetrad degenerate regularly and two remain functional (Text-Fig. 19). Counts of pollen grains from different anthers of the same flower as well as those from different flowers in *P. involucrata* showed that the dyads form 84–87% of the grains of an anther loculus, the remaining ones being made up of full tetrads, monads, triads or nullads (Text-Fig. 20). An examination of the microtome sections of flower-buds has shown that as in other types, in this also the fertile microspores do not bear any relation to the anther tapetum but are indiscriminately oriented in the anther loculus.

S′-type or modified Styphelia-*type.*—In this type also the tetrads start development with four similar microspores as in A- and P-types. During further development, three microspores of each tetrad invariably degenerate and only one remains functional. The mature pollen therefore consists of a single large grain (monad). This type has been reported by Smith-White (1955 *a*) in about 14 species of *Leucopogon* but was not met with in the present studies.

S-type or Styphelia-*type.*—In this type, before cytokinesis of the microsporocyte takes place and even before the special wall of callose breaks down, three of the microspore nuclei group together and the fourth occupies an isolated position on the opposite side of the cell (Text-Figs. 23, 24, 29, 32 and 33). Walls are then formed around the nuclei and result in one large functional and three small non-functional cells (Text-Figs. 25 and 34). Only the functional cell enlarges further and undergoes nuclear division while the non-functional cells degenerate

(Text-Figs. 30, 37 and 39). They later become so obliterated that they may escape casual observation (Text-Fig. 31). Mature monads can therefore be mistaken for single grains. The functional grain becomes 2-celled and accumulates abundance of starch (Text-Figs. 26 and 31). It is usually tricolporate, 4-porate ones being noticed rarely (Text-Fig. 27). Meiotic divisions were followed in *Styphelia adscendens* ($n = 4$), *Astroloma humifusum* ($n = 12$), *Monotoca empetrifolia* ($n = 12$) and *M. linifolia* ($n = 12$) and were found to proceed normally (Text-Figs. 21, 22 and 28).

The pollen development in *Monotoca* sp. deserves special mention. In *M. scoparia* the pollen consists of all types from tetrads to monads and therefore cannot be classed under the S-type as Smith-White (1955 *a*) has done but under the A-type. In other species examined it is predominantly of the S-type. These species are interesting in that the pollen mother cells as well as developing monads are ellipsoidal and show structural polarity like the megaspore mother cells and tetrads of most angiosperms (Text-Figs. 32–34). The young monad is markedly lobed due to deep furrows (Text-Figs. 35 and 36) though it becomes more rounded later (Text-Fig. 37).

It is interesting to notice that the S-type of pollen development closely resembles that in the well-known Cyperaceae.

Particulars regarding the dimensions of pollen grains are given in Table I. In T-type, P-type and *Monotoca* the maximum diameter of the tetrad is given as D and the diameter of the individual grains as *d*. D/*d* is given as an index to the globularity of the tetrad as Oldfield (1959) has done in the Ericaceae. Each diameter represents an average of ten readings.

TABLE I

Members studied

Genus and species	Pollen type	D(μ)	*d*(μ)	D/*d*
TRIBE EPACRIDEAE:				
Richea sprengelioides Br. ..	Single grains	..	15·0	..
R. procera F. Muell. ..	,,	..	24·8	..
R. milligani F. Muell. ..	,,	..	25·5	..
R. dracophylla Br. ..	T-type	34·4	23·7	1·45
R. pandanifolia Hook. ..	,,	31·0	22·1	1·40

TABLE I—*Contd.*

Genus and species	Pollen type	D(μ)	d(μ)	D/d
R. scoparia Hook. ..	T-type	38·7	28·2	1·37
R. gunnii Hook. ..	,,	32·1	20·9	1·53
Dracophyllum milligani Hook.	,,	26·7	19·8	1·35
Sprengelia incarnata Sm. ..	,,	33·2	26·7	1·24
Archeria combei W. M. Curtis	,,	39·5	29·0	1·36
Lysinema ciliatum Br. ..	,,	39·8	33·4	1·19
Epacris impressa Labill. ..	,,	61·6	46·1	1·33
E. microphylla Br. ..	,,	49·5	31·1	1·26
E. virgata Hook. ..	,,	58·9	49·6	1·18
E. lanuginosa Labill. ..	,,	57·9	48·6	1·70
Prionotes cerinthoids Br. ..	,,	39·2	28·6	1·37
TRIBE STYPHELIEAE:				
Styphelia adscendens Br. ..	S-type	..	64·6	..
Astroloma humifusum Br. ..	,,	..	89·7	..
A. pallidum Br. ..	,,	..	100·2	..
Conostephium pendulum Benth.	,,	..	29·8	..
Pentachondra pumila Br. ..	T-type	41·5	29·3	1·41
P. involucrata Br. ..	P-type	50·6	33·8	1·49
Cyathodes parvifolia Br. ..	T-type	32·9	23·4	1·41
C. glauca Labill. ..	,,	58·6	40·0	1·46
C. divaricata Hook. ..	,,	48·4	38·5	1·26
C. acerosa (= *C. juniperina* Druce)	,,	26·1	19·3	1·35

TABLE I—*Contd.*

Genus and species	Pollen type	D(μ)	*d*(μ)	D/*d*
C. adscendens Hook. (=*C. petiolaris* Druce)	T-type	32·3	22·8	1·41
C. straminea Br. ..	,,	47·5	35·5	1·34
C. dealbata Br. ..	A-type	..	39·8	..
Trochocarpa gunnii (Hook.) Benth.	T-type	34·7	24·1	1·44
T. thymifolia Spreng. ..	,,	42·3	32·5	1·31
T. cunninghami W. M. Curtis	,,	53·3	41·3	1·28
Lissanthe montana Br. ..	,,	34·6	23·9	1·45
L. strigosa Br. ..	,,	61·4	37·0	1·66
Acrotriche serrulata Br. ..	,,	44·6	33·4	1·35
Leucopogon hookeri Sond. ..	,,	51·1	37·7	1·35
L. ericoides Br. ..	S-type	..	31·5	..
L. virgatus ..	,,	..	27·2	..
L. collinus Br. (= *L. ciliatus* A. Cunn.)	,,	..	30·6	..
Monotoca scoparia Br. ..	A-type	33·0	27·1	1·22
M. empetrifolia Br. ..	S-type	23·7	17·3	1·37
M. linifolia W. M. Curtis ..	,,	27·5	23·3	1·18

DISCUSSION

The parallelism in the ontogeny and homologies of the male and female gametophytes in angiosperms is well known. Darlington and La Cour (1941) have shown that the meiotic divisions in the microspore and megaspore mother cells in *Fritillaria* sp. are closely similar even in chiasma frequency. In the stable triploid *Leucopogon juniperinus*, Smith-White (1955 *a*) described how haploid and diploid sets

of chromosomes are eliminated from the megaspore and microspore mother cells during meiotic divisions so that the pollen is always haploid ($n = 4$) and the embryo-sac always diploid ($2n = 8$). Probably due to the necessity of being transported, the male gametophyte suffered greater reduction while in the female gametophyte the function of nourishing the embryo necessitated the retention and persistence of some more prothallial tissue. The essential homology of the gametophytes is, however, quite evident from the 8-celled embryo-sac-like pollen grains of *Hyacinthus* sp. (Stowe, 1930).

The various types of pollen development described in Epacridaceae provide some more instances of parallelism in the ontogeny of male and female gametophytes. In several Epacridaceae (as in most angiosperms) all the 4-microspore nuclei resultant of the meiotic divisions are functional; this has a parallel in the tetrasporic type of embryo-sac development in which all the four megaspore nuclei remain functional. The P-type of pollen development, in which two out of the four microspores function, is paralleled by the bisporic type of embryo-sac development. The monad type of pollen development (S′-type and S-type), in which three microspores are regularly eliminated, finds a parallel in the monosporic type of embryo-sac development.

Smith-White (1955) regarded the S-type of pollen development as the most specialised one and derived from T-type. He supposed that this is genetically or genotypically controlled and that a breakdown of the delicate mechanism controlling the polarity in the cell results in a reversion to the other primitive types, *viz.*, A- and S′-types. The present author, however, feels that the various types are stable and independent steps in the evolution of the pollen from the single grains culminating in the monad types, just like the various types of embryo-sac development.

A perusal of the chromosome numbers and floral structure in the two tribes of the Epacridaceae shows that the Epacrideae is the relatively primitive and more homogeneous tribe. In the majority of genera of this tribe, the haploid chromosome number is 13 and all species of a genus have the same chromosome number (Smith-White, 1955 *a*). *Epacris serpyllifolia* (Smith-White, 1955 *a*; present studies) and *Prionotes cerinthoids* (Venkata Rao, 1959) are polyploids with $n = 26$. *Sprengelia* sp. have $n = 12$ and *Sphenotoma* sp. $n = 6$ and 7 (Smith-White, 1955 *a*). The flowers in this tribe are commonly hermaphrodite and are either devoid of nectaries or provided with scale-like lobes. The stamens are free from the petals in *Prionotes*, *Richea*, *Sprengelia* and *Dracophyllum*. The carpels are multiovulate and the fruits capsular. As already described, the pollen grains in the majority of members are in tetrads, single grains also being noticed in some species of *Richea*.

In the tribe Styphelieae, the chromosome numbers are more varied and range from $n = 33$–24, 22, 14, 12, 11, 10, 9, 8, 7, 6 and 4. Sometimes there is variation of chromosome numbers within species of a genus, *e.g.*, *Leucopogon* ($n = 33$ 24, 14, 12, 11, 10, 9, 7, 6 and 4), and *Cyathodes* ($n = 12$, 10 and 9). Species with $n = 13$ are relatively rare,

e.g., *Pentachondra involucrata* (present studies). In several genera the flowers are provided with conspicuous, 4- or 5-lobed vascularised nectary. The stamens are epipetalous and the carpels uniovulate. The fruits are drupaceous, often coloured and succulent (*e.g.*, *Cyathodes* sp.) and adapted for animal dispersal. Evolution is noticed of different sexual systems as dioecy and gynodioecy [*Cyathodes divaricata*, *C. parvifolia*, *Lissanthe montana*, *Leucopogon hookeri*, *Monotoca scoparia*, *M. elliptica* (Smith-White, 1955), *M. linifolia*, *M. empetrifolia* (present studies) and *Cyathodes colensoi* (Godley, 1957]. The pollen in this tribe shows a variety of patterns from tetrads to monads.

In general, single pollen grains which are found in the majority of angiosperms can be taken as the primitive type. Aggregation of the grains into tetrads (Droseraceae, Apocyanceae, and Juncaceae) or packets (Mimosaceae) or pollinia (Asclepiadaceae and Orchidaceae) can be regarded as an evolutionary feature since it has the obvious advantage of enhancing the chances for fertilization; the aggregation is associated with intricate pollination mechanisms in the last two families.

The single grains of *Richea* sp. can therefore be taken as the starting-point. They are spherical and tricolporate with fusiform colpi and conform to one of the basic ancestral dicotyledonous types (Wodehouse, 1936). The tendency towards aggregation of the grains into tetrads marks the first step in the evolution of pollen. This is noticed in all genera of the Epacrideae. Evolution has not progressed beyond this level in the Epacrideae, though a tendency towards the elimination of some of the microspores of a tetrad by irregularities in meiotic division is noticed in *Richea sprengelioides*.

The presence of single grains as well as tetrads of pollen in Epacrideae and Ericaceae, the close similarity in the external features of their pollen grains and the occurrence of $n = 13$ or multiples thereof in both taxa indicate that they are closely related and have probably evolved from common ancestors.

Since single grains have not so far been encountered in the Styphelieae, the tetrad can be taken as the basic type in this tribe, specialisation in which led to the evolution of different patterns of pollen development. The close similarity in the structural features of the fertile grains in both tribes of the Epacridaceae show that they are fundamentally similar and have evolved from the same ancestral type. Since the functional microspores in A-, P-, S′- and S-types of pollen do not bear any spatial relation to the anther tapetum it is evident that the mechanism which operates and determines the number of functional microspores in the tetrad is not an intercellular but an intracellular one (chromosomal or cytoplasmic) as Smith-White also believed.

Of the different patterns of pollen development in Styphelieae, the A-type seems to be the least specialised. In *Astroloma* species and *Cyathodes dealbata*, this type is associated with irregularities in meiotic divisions. Intracellular polarity does not seem to be operative

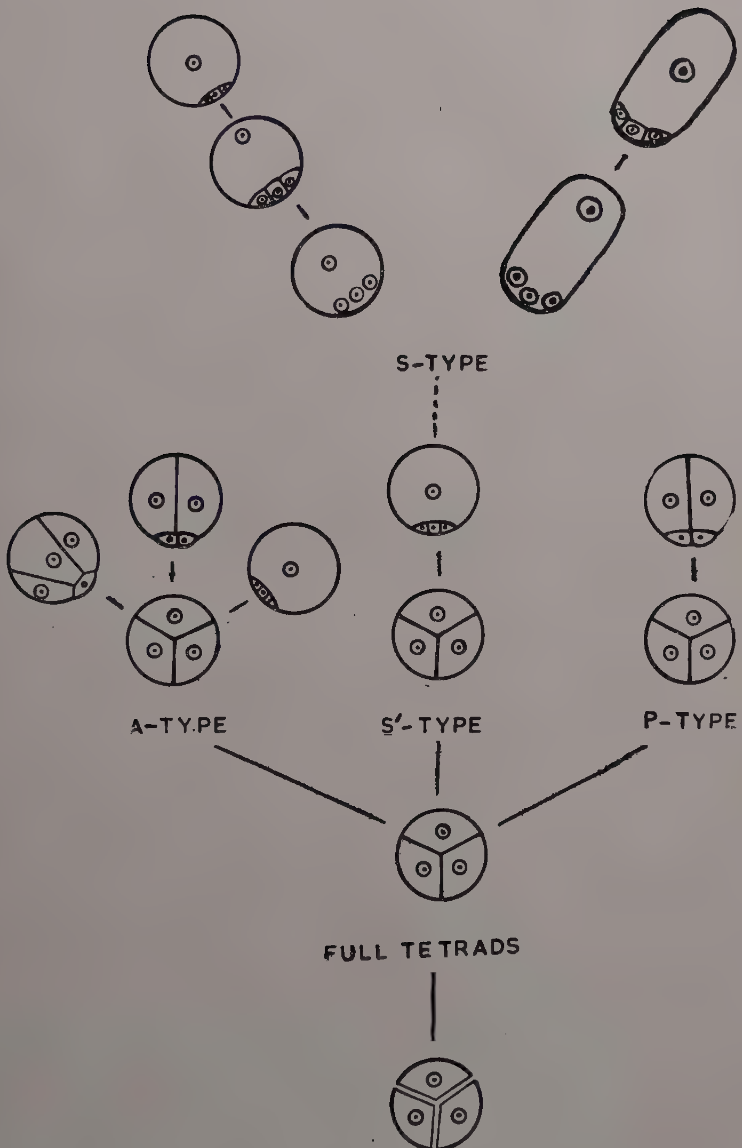
at this stage. Since the elimination of some microspores is due to chromosomal aberrations and deficiencies, it occurs in a sporadic and unpredictable manner. Formation of relatively thick cell-walls between the microspores also probably leads to an early degeneration of some microspores by preventing the passage of suitable nuclear materials between the normal and deficient microspores as Barber (1942) found in some Orchidaceae. The A-type of development resembles the condition in *Richea sprengelioides* the only difference being that while in this species the microspores of a tetrad separate out, they remain permanently united in the A-type.

P- and S′-types of pollen development represent a more advanced stage since they are characterised by a fixidity in the number of functional spores in a tetrad, 2 in P-type and 1 in S′-type. The meiotic divisions in the members examined proceed normally so that the elimination of the functionless microspores is not due to chromosomal deficiencies or aberrations. The regularity in the pattern of development and the definiteness in the number of viable spores shows that the development is controlled by an intracellular cytoplasmic polarity which itself may have had a genetic origin. The polarity in these two types becomes operative at a relatively late stage in the ontogeny of the microspores, *i.e., after* they are organised as cells.

In S-type of pollen development, the cytoplasmic polarity becomes operative at an earlier stage than in P- and S′-types, even *before* the formation of walls in the microsporocyte. It is also evident from a slight difference in the staining capacity of the cytoplasm; the cytoplasm on the sterile pole stains a little deeper than that on the fertile pole (Text-Figs. 23, 24 and 29). While the quadrate arrangement of the microspore nuclei in T-, A-, P- and S′-types of pollen development resembles that of the megaspore nuclei in the coenomegaspores of *Peperomia* and *Penaea* types of embryo-sac development, the 1+3 grouping of nuclei in the S-type closely resembles that in the coenomegaspores of *Drusa*, *Fritillaria* and *Plumbagella* types. The functional and non-functional microspores in S-type are markedly dissimilar in size, a condition commonly noticed in the megaspore tetrads.

In *Styphelia*, *Astroloma* and *Leucopogon*, since the microsporocytes are spherical, there is no morphological difference in the poles of the cell. In some *Monotoca* sp., however, the microsporocyte as well as the functional microspore are ellipsoidal from early stages of development. In the opinion of the author, the monad type of pollen development in *Monotoca* sp. in which the microspore mother cells are functionally as well as structurally bipolar and in which the polarity becomes operative from a very early stage in the ontogeny of pollen, represents the most advanced type of pollen development in the Epacridaceae. The views of the author regarding the evolution and interrelationships among the various pollen types in the family are represented in Text-Fig. 40.

The uniformity in floral structure, chromosome numbers and pollen types in the Epacrideae on the one hand, and the complexity of floral



TEXT-FIG. 40. Evolution of pollen types in the Epacridaceae according to the views of the author.

structure and diversity in chromosome numbers and pollen types in the Styphelieae on the other, suggest that the two tribes are either

diphyletic or that the Styphelieae have diverged very early from the common ancestral stock and underwent greater diversification and specialisation.

The presence of S-type of pollen development in genera with diverse chromosome numbers and the occurrence of different types of pollen development within the the same genus, *e.g.*, T- and P-types in *Pentochondra*, T- and A-types in *Cyathodes*, T-, S′- and S-types in *Leucopogon*, show that the different types have evolved independently in the different genera.

SUMMARY

Two more types of pollen development, *viz.*, single grains and P-type have been added to the four described by Smith-White in the Epacridaceae and the evolutionary lines are suggested. Irregularities in meiotic divisions seem to be the cause of elimination of some of the microspores of the tetrad in A-type. Fixation of this tendency as cytoplasmic polarity (probably of genetic origin) led to the evolution of other types of pollen development, namely P-, S′- and S-types.

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STUDIES IN THE UMBELLALES

II. The Vegetative Anatomy*

By S. P. Mittal ‡

School of Plant Morphology, Meerut, India

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Introduction

The order Umbellales has attracted very little attention so far from the morphological and anatomical points of view. Solereder (1908) excellently reviewed the literature on the vegetative anatomy of the order in his monumental work *Systematic Anatomy of the Dicotyledons.* Many anatomists reported the presence of medullary bundles in the stem (Trécul, Sanio, Cedervall, quoted from Solereder, 1908; Viguier, 1906; and Metcalfe & Chalk, 1950) and petioles (Petit, Plitt, quoted from Solereder, 1908; and Metcalfe & Chalk, 1950) of some members of the Araliaceae and Umbelliferae. In some Araliaceae and Umbelliferae (*Eryngium* with a monocotyledonous habit, *Siler* and *Mulinum*) a few cortical bundles have also been reported in stems. All these anatomists also reported the presence of secretory ducts in the Araliaceae and Umbelliferae and secretory cells in the Cornaceae.

Sinnott (1914), who for the first time studied the nodal structure in about 165 families and 400 genera of the dicotyledons, recorded multilacunar condition in the Araliaceae and the Umbelliferae and trilacunar condition in the Cornaceae. He also reported that there are more leaf-traces in the Umbelliferae than in the Araliaceae.

Hoar (1915), making a detailed study of the stem anatomy, found that while in the Cornaceae the parenchyma in the wood always remains scattered in the growth rings and the vessels have scalariform perforations, in the Araliaceae and Umbelliferae it remains grouped about the vessels and the latter have simple pores. He used these two important points in establishing the relationships of the three families of the Umbellales.

Joshi (1932) studied the structure, arrangement and course of vascular bundles in the stem and leaves of *Heptapleurum venulosum*. He traced the course of a normally oriented bundle from the base of

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* Research contribution No. 23 from the School of Plant Morphology, Meerut College, Meerut.

‡ Present address: Principal and Professor of Botany, R. M. P. Degree College, Narsan, (Dist.) Saharanpur (U.P.).

the petiole higher up and found that it becomes inversely oriented on account of rotation through 180°. He also recorded some cortical bundles in the stem and showed the node to be multilacunar.

The present study of the nodal anatomy of the available species was undertaken with a view to see if it throws some light on the inter-relationships of the three families in general and the suggested separation of the Cornaceae in particular.

Material and Methods

The material studied here includes 23 species which were collected by the author from Meerut, Dehra Dun, and Mussoorie hills. Fixed material of one species was supplied by Dr. Venkatachary of Udaipur and *Hydrocotyle javanica* was placed at the author's disposal by Dr. Y. D. Tiagi of Sagar.

Serial microtome sections were cut and studied. Besides these, thick sections (as thick as 80 microns) of nodes of Araliaceae were also cut by sliding microtome and studied under a binocular microscope. Slides thus prepared were stained with safranin-fast green and the combination was found very satisfactory. The species studied here are detailed in Table I.

Table I

Name of the species		Place
Araliaceae:		
1. *Heteropanax fragrans* Seem.	..	F.R.I.
2. *Heptapleurum venulosum* Seem.	..	F.R.I.
3. *Hedera nepalensis* Koch	..	Mussoorie
4. *Polyscias balfouriana* Bailey	..	Udaipur
5. *Tupidanthus calyptratus* Hook. f. & Thoms.		F.R.I.
Umbelliferae:		
6. *Centella asiatica* (Linn.) Urban	..	Meerut
7. *Hydrocotyle javanica* Thunb.	..	Darjeeling
8. *Coriandrum sativum* Linn.	..	Meerut
9. *Oenanthe stolonifera* Wall.	..	Meerut

TABLE I—*Contd.*

Name of the species		Place
10. *Bupleurum tenue* Don	..	Mussoorie
11. *Foeniculum vulgare* Gaertn.	..	Meerut
12. *Carum copticum* Benth.	..	Meerut
13. *Pimpinella diversifolia* (Wall.) DC.	..	Mussoorie
14. *Apium ammi* (Jacq.) Urban	..	Dehra Dun
15. *Ammi majus* Linn.	..	Meerut
16. *Peucedanum graveolens* Benth.	..	Meerut
17. *Heracleum candicans* Wall.	..	Mussoorie
18. *Cuminum cyminum* Linn.	..	Meerut
19. *Daucus carota* Linn.	..	Meerut
CORNACEAE:		
20. *Cornus macrophylla* Wall.	..	Mussoorie
21. *C. capitata* Wall.	..	Mussoorie
22. *C. florida* Linn.	..	F.R.I.
23. *Marlea begonifolia* Roxb.	..	F.R.I.

F.R.I. = Forest Research Institute, Dehra Dun.

OBSERVATIONS

(1) *Araliaceae*

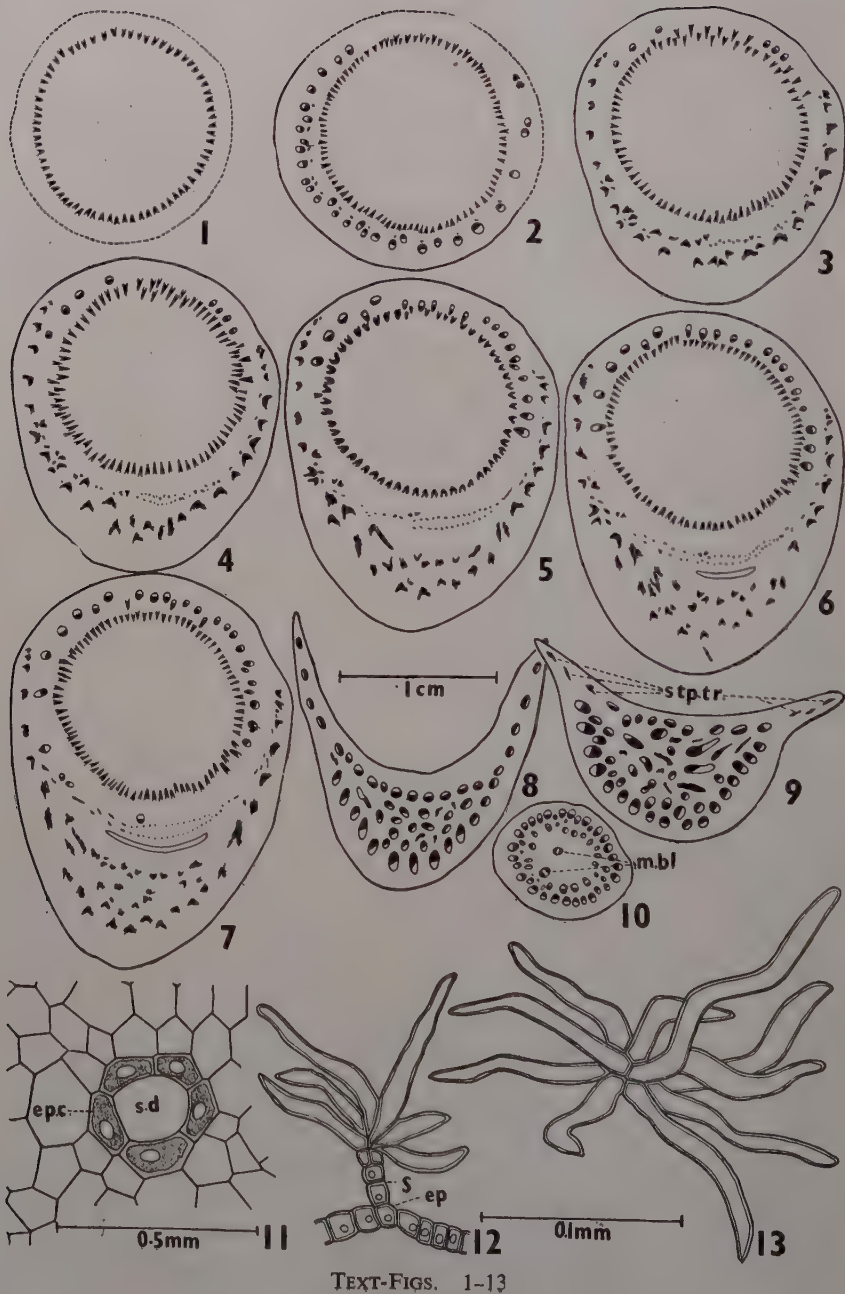
Of the five species of Araliaceae, *Heteropanax fragrans*, *Polyscias balfouriana* and *Tupidanthus calyptratus* are small trees while *Hedera nepalensis* and *Heptapleurum venulosum* are climbing shrubs. The leaves, arranged on very short internodes, are generally alternate, stipulate (*H. fragrans*, *H. venulosum* and *T. calyptratus*) or exstipulate and pinnately or palmately compound. *H. nepalensis* is very interesting in exhibiting adventitious adhesive rootlets (endogenous in origin) and simple polymorphic exstipulate leaves.

As the nodal and the vegetative anatomy of the five species studied is more or less similar, the condition in *H. fragrans* alone will be described in detail and attention will be drawn to other species wherever necessary.

A transverse section of the internode shows a ring of numerous vascular bundles that are alternately large and small (Text-Fig. 1). In *T. calyptratus* they seem to be much extended radially. Every one of them is provided with a prominent and a small sclerenchymatous cap on its outer and inner sides respectively. *H. venulosum* resembles *H. fragrans* in this respect, while the other three species differ in lacking inner sclerenchymatous caps. Four cortical bundles are also seen lying irregularly in *H. venulosum* (*cf.* Joshi, 1932).

In the sub-nodal region vascular bundles start enlarging and branching. About 25 traces (15 in *H. venulosum* and *T. calyptratus*, 17 in *P. balfouriana* and 7 in *H. nepalensis*) from this vascular cylinder diverge out into the cortex forming a horse-shoe shaped pattern (Text-Figs. 2–7). These constitute the leaf-traces that enter the leaf-base as the latter separates off (Text-Figs. 6–9). Of these traces some on each side supply the stipules (Text-Fig. 9, *stp.tr*) while the remaining ones finally organise themselves into the vascular cylinder of the petiole (Text-Figs. 9, 10). The remaining bundles of the parent stele branch and anastomose and constitute the vascular cylinder of the internode above (Text-Fig. 2). Just as the leaf-traces are diverging out some of the middle ones, leave behind some very small traces, that organise themselves into a vascular cylinder of the axillary branch (Text-Figs. 3–7).

A transverse section of the petiole shows a single-layered epidermis followed by 6–10 layers of collenchyma merging into many-layered parenchymatous cortex. There are numerous vascular bundles arranged in one (*P. balfouriana*) or more or less two (*H. fragrans, H. venulosum* and *T. calyptratus*) distinct rings (Text-Fig. 10). *H. nepalensis* shows only 5–8 vascular bundles arranged in one ring thus lacking medullary bundles (*see* also Petit, 1886 and Plitt, 1887 quoted from Solereder, 1908). The outer ring contains generally large bundles each capped with patches of some densely staining cells on the outer as well as on the inner side. It is quite likely that in more mature material these patches become sclerenchymatous as described by Viguier (1906). The bundles of the inner ring, generally termed as the medullary bundles, are fewer, smaller and with less prominent caps. Curiously enough these are all inversely oriented and have their xylem pointing outward as is the case in many other genera (*see* Viguier, 1906) of the family (Text-Fig. 10). Some of these are laterally oriented while a few showed xylem patches on both the sides of the phloem. It is surprising that Viguier (1906, Text-Fig. 35) described and figured all these medullary bundles as normally oriented and interpolated in between bundles of the outer ring. Solereder (1908, p. 945), however, misquoted him when he described these bundles as inversely oriented. Some other bundles with indistinct orientation are found scattered in between



TEXT-FIGS. 1–13

TEXT-FIGS. 1–13. *Heteropanax fragrans*. Figs. 1–9. Serial transverse sections of a node from base upward. Fig. 1. Shows only the vascular cylinder of the internode. Figs. 2–7. Show origin of the numerous leaf-traces and their entrance into the leaf-base. Figs. 8–9. Show the stipular traces (*stp.tr.*) and the irregular arrangement and orientation of the vascular bundles in the leaf-base and at the base of the petiole. Fig. 10. Represents the transverse section of the petiole. Note the arrangement and the inverse orientation of the vascular bundles of the inner ring and two central medullary bundles (*m.bl.*) with xylem pointing outwards on both sides and phloem in the middle. Fig. 11. Shows a secretory duct (*s.d.*) with a lining of five epithelial cells (*ep.c.*). Fig. 12. Shows a stellate epidermal hair with a uniseriate stalk (*s*). Fig. 13. A stellate hair from above.

these two rings. In *H. fragrans* two or more bundles with xylem pointing outward on opposite sides and phloem in the middle are seen in the pith (Text-Fig. 10, *m.bl.*).

In *H. fragrans*, unicellular and multicellular (Text-Figs. 12, 13) stellate epidermal hairs are abundant on the flowering shoots. A single stellate hair consists of a basal stalk (Text-Fig. 12, S) of 2–4 small squarish cells placed one above the other each with dense cytoplasm and a prominent nucleus and a few terminal cells that bear 4–10 projections (Text-Figs. 12, 13) pointing in different directions. Hairs with biseriate stalks, as reported in *Hedera helix* and some other members of the family (Solereder, 1908) are rare.

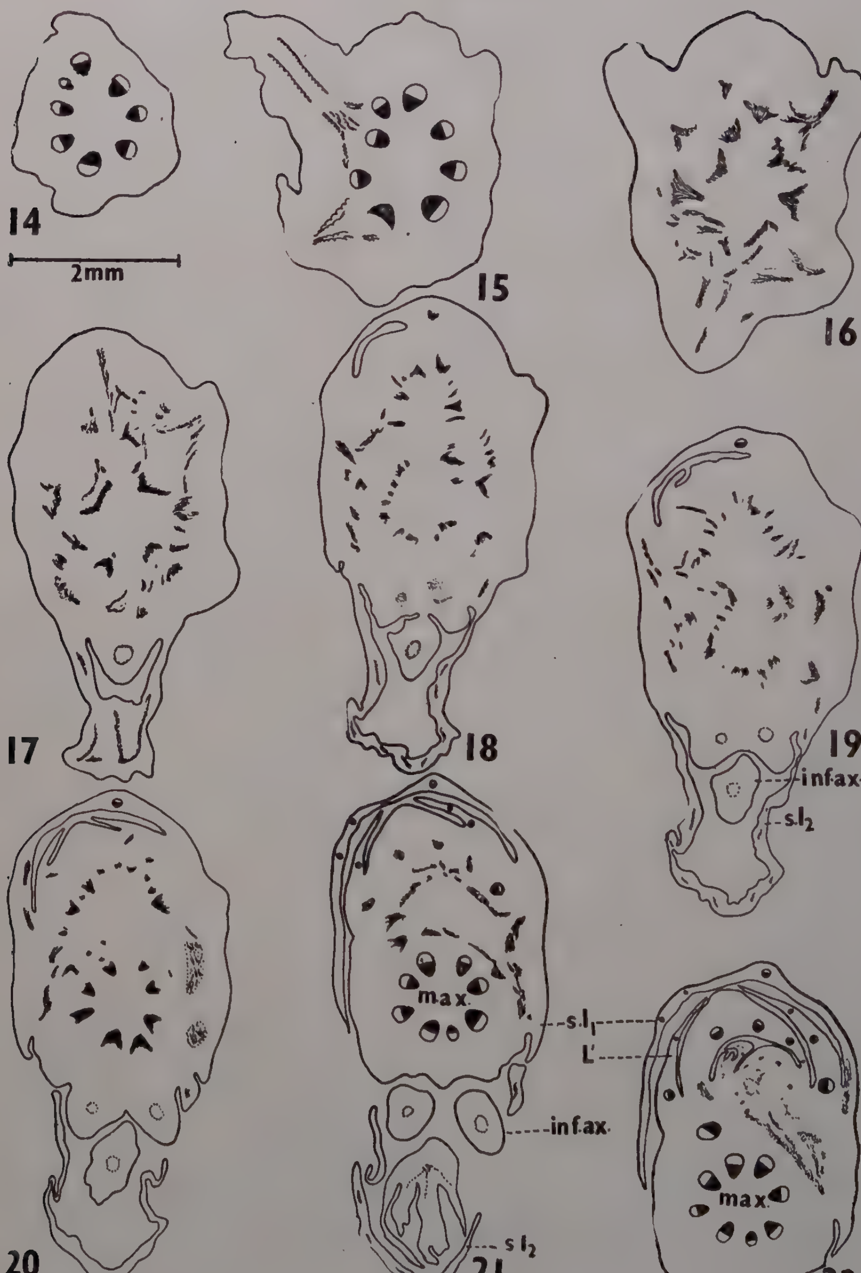
Secretory ducts (Text-Fig. 11, *s.d.*) which are characteristic of the family are scattered in all parts of the plants. They are more frequently found accompanying vascular bundles, generally outside the pholem and rarely with xylem. However, these ducts vary considerably in size and number. All such ducts arise schizogenously and each has a lining of 5–9 small thin-walled somewhat columnar cells with prominent nuclei and dense cytoplasm (Text-Fig. 11, *ep.c.*). These epithelial cells probably secrete some resinous or gummy substance. Besides these secretory ducts some secretory cavities, which are very small and continue for short distance, may also be found.

Certain cells containing large compound star-shaped white shining crystals of calcium oxalate are commonly found. These 'crystal sacs' remain more or less filled with the druses.

(2) *Umbelliferae*

Members of the Umbelliferae are small glabrous herbs characterised by hollow internodes and simple or profusely pinnately dissected leaves with sheathing bases. In *Hydrocotyle javanica* and *Centella asiatica*, however, the leaves are entire with two scarious stipules each. In *Bupleurum tenue* the leaf is sessile and entire. The sheathing bases more or less enclosing the axillary branches continue into a short flattened (*Coriandrum sativum*, etc.), grooved (*C. asiatica*, etc.), angular (*Foeniculum vulgare*) or cylindrical (*H. javanica*) petiole.

As the nodal anatomy of *C. asiatica* is somewhat different and complicated in comparison to other members studied it will be described separately in detail.



TEXT-FIGS. 14–22. *Centella asiatica.* Serial cross-sections of a node from base upward showing the vascular supply to the adventitious roots, scale-leaves ($s.l_1$, $s.l_2$) and to the inflorescence axes (*inf.ax.*).

A transverse section of the rhizome of *C. asiatica* shows a ring of numerous vascular bundles each with a small sclerenchymatous cap outside. The cortical and pith cells along with some phlcem ones remain completely filled with starch grains that give blue colour with iodine.

The node on the creeper bears a pair of unequal scale leaves (Text-Figs. 26, 27, $s.l_1$, $s.l_2$.) which in their axils have one and 3–4 buds. Whereas the buds in the axil of lower small scale leaf develop into inflorescences (Text-Fig. 26, *inf.ax.*), that in the axil of upper bigger scale leaf develops into a vegetative shoot. Besides these structures, there are also found some buds which produce adventitious roots.

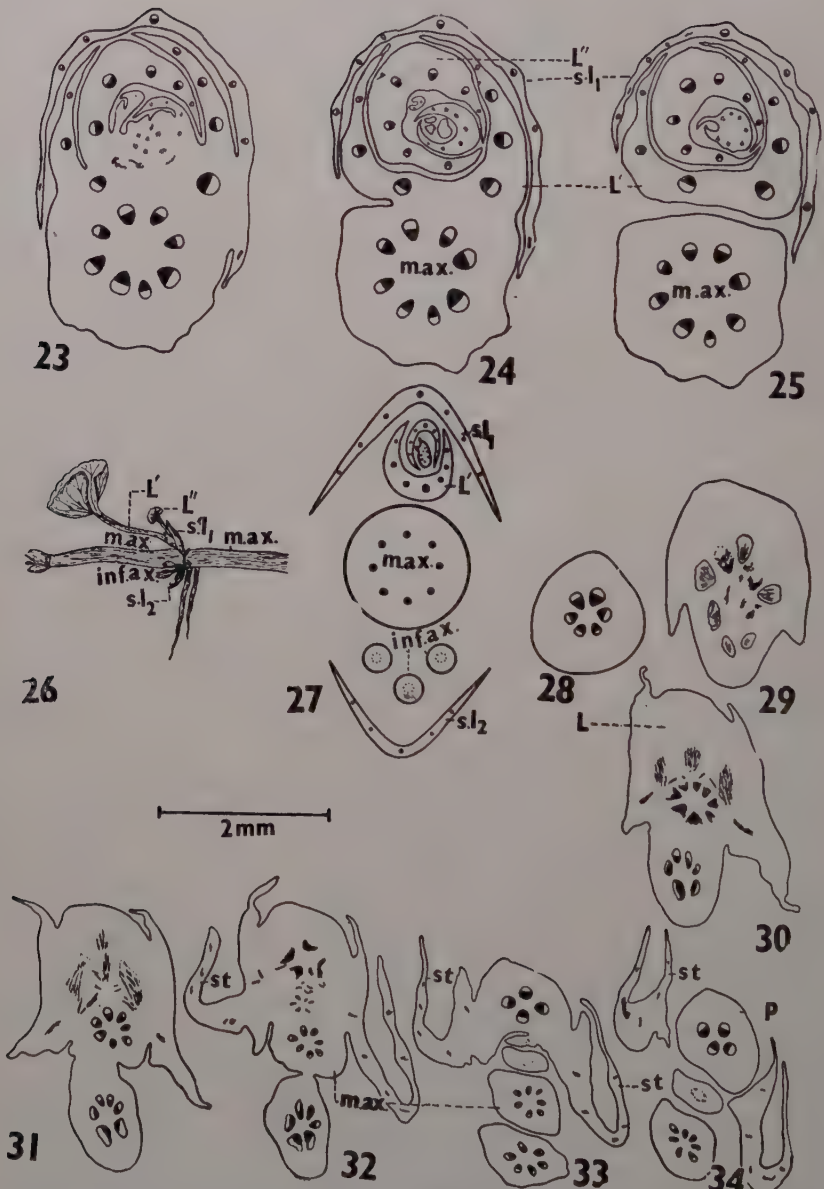
The stele in the sub-nodal region consists of a ring of some eight vascular bundles (Text-Fig. 14). Traces arise directly from these bundles of the internode constituting the vascular supply of the adventitious roots (Text-Fig. 15). A little higher up 3 or more traces either from the same or different gaps are given off to each of the two scale leaves, the upper one always receiving more than the lower one (Text-Figs. 16–22). Simultaneously the vascular supply of the axillary peduncles and the vegetative bud consisting of a number of traces separates off (Text-Figs. 16–21). The leaves on the axillary shoot of the upper scale leaf and elsewhere always receive 5 or 7 traces each (Text-Figs. 23–25, 27, L′, L″). It is also to be pointed out that the first foliage leaf of the axillary bud always remains adnate with the main axis for some distance (Text-Figs. 24, 25, L′).

Mitra and Majumdar (1952) have reported a multilacunar node in *C. asiatica*. Stipules are supplied by one or two very small traces from the extreme foliar bundles. These vascular traces of the stipules, which, however, do not continue for long distance, have been overlooked by Mitra and Majumdar. The other leaf-base bundles come closer and the two extreme ones on each side of the midrib bundle fuse and thus there become only five bundles in the base of the petiole.

The petiole is fistular having a central cavity and has a groove on the adaxial surface. Serial transverse sections of the petiole reveal that the lamina of the leaf-blade continues over the petiole along the margins of the adaxial groove (Text-Figs. 35–45, *la*, P). Just before the merging of the petiole into the lamina the cavity is lost (Text-Fig. 45) and the five bundles anastomose into a mass (Text-Figs. 46–49), from which the veins come out and diverge into the leaf-blade.

The node in *H. javanica* is trilacunar (Text-Figs. 28–34) and the wings (Text-Figs. 32–34, *st*) of the leaf-base (Text-Fig. 30, L) are much more vascularised than those of *C. asiatica*. The leaf-base soon after the separation of the stipules forms a cylindrical solid petiole (Text-Fig. 34, P) which generally contains four vascular bundles only.

A mature internode in all other members studied shows in a transverse section a ring of vascular bundles ranging from 12 (*B. tenue*) to as many as 30–40 (*Ammi majus*). Near the nodal region all the



TEXT-FIGS. 23–34. *Centella asiatica*. Figs. 23–25. In continuation of Fig. 22. Note the seven bundles in first and second foliage leaves (L′, L″). Fig. 26. A node showing different structures. Fig. 27. A diagrammatic representation of the transverse section of the node. Figs. 28–34. *Hydrocotyle javanica*. Serial transverse sections of a node from base upward. Note the trilacunar condition of the node causing three gaps in the main stele. Figs. 31–33. Show the supply of the stipules from the three foliar bundles and finally forming the vascular cylinder of the petiole (P) in Fig. 34.

bundles as usual increase in size, branch and anastomose among themselves. Many traces in this region diverge out from the main cylinder and, after contributing some small branches for the vascular supply of the axillary branch, pass out into the sheathing leaf-base. Thus, the nodes are multilacunar, the number of leaf-traces ranging from 7 to as many as 15–17. Sometimes this number varies considerably in different leaves of the same plant.

The true petiole in all the species but *F. vulgare* and *P. graveolens*, is represented by a short and flattened sheathing leaf-base. In *Daucus carota*, the leaves have a long or a short petiole each with an adaxial groove. On studying an entire leaf under the dissecting binocular it becomes clear that the wings of the sheathing base continue upward into the margins of the dissected lamina. The foliar traces gradually decreasing upward in number arrange themselves in a more or less crescent-shaped fashion. All these bundles in the uppermost portion of the leaf-base or at the apex of the petiole enlarge, anastomose laterally and enter as finer branches into the leaf segments. In *F. vulgare* the petiole, quite distinct from the leaf-base, is long cylindrical and contains 3 to many bundles arranged in a ring. Metcalfe and Chalk (1950, Fig. 165 B) show 17 bundles in the petiole of this species.

Oil ducts of the usual type occur in all the species studied here. Each oil duct consists of a circular cavity enclosed by 10–20 small more or less squarish thin-walled cells which are rich in cytoplasmic contents. During development 3–4 cells begin to separate from each other enclosing a small space in the centre. These divide radially into about a dozen of cells which surround a fairly large cavity—the oil duct. Beside, there are found scattered in groups specially in association of the vascular tissue some needle-like or branched yellowish crystals of some unknown chemical compound probably hesperidine (Solereder, 1908).

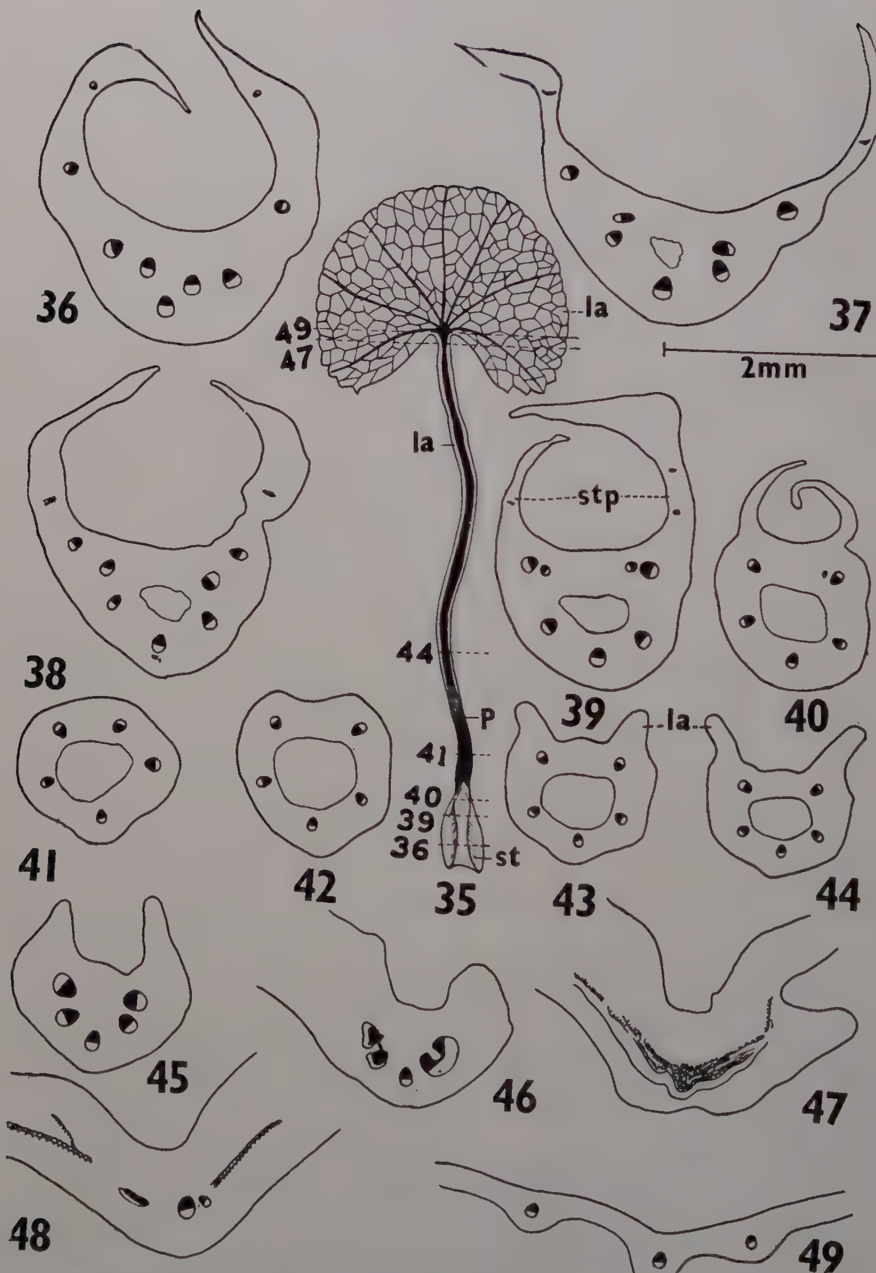
(3) *Cornaceae*

Cornaceae differs widely from Araliaceae and Umbelliferae in its vegetative characters. All the four species of the family studied here are small trees with simple, exstipulate, opposite decussate (*Cornus*) or alternate (*Marlea begonifolia*) leaves.

As the anatomy of the vegetative organs in all the three species of *Cornus* in question is almost identical, only a general account will be given and attention will be drawn to a species wherever necessary.

The epidermal cells of the angular internode (Text-Figs. 50, 60) are radially elongated (*C. macrophylla*) and produce many-layered (*C. capitata*) cork composed of rectangular cells that remain filled with dark brown substance.

The vascular cylinder of the internode contains a ring of numerous distinct bundles (*C. macrophylla*) (Text-Fig. 50, *m.ax.*) or it may be continuous as in *C. florida* (Text-Fig. 60) and *C. capitata*. In the subnodal region two groups of three bundles each become more prominent on opposite sides and diverge out through the cortex for their respective



TEXT-FIGS. 35–49. *Centella asiatica*. Fig. 35. An entire leaf showing stipules (*st.*), petiole (P) and the leaf-blade. Note the continuation of lamina over the petiole. Figs. 36–49. Serial cross-sections of leaf from leaf-base to the lamina upward. Note the central cavity and the continuation of the lamina along the considerable length of the petiole. Note the anastomosis of the foliar bundles at the junction of the leaf-blade in Fig. 47.

leaf-bases (Text-Figs. 51–53, 1, 2, 3; 61, 62). The medians of these leaf-traces are particularly large and while passing outward leave some very small vascular traces on each side (Text-Figs. 52, 53, 61, 62). These supply the corresponding one (*C. capitata* and *C. florida*) (Text-Figs. 61, 62, *ax.b.*) or two (*C. macrophylla*) (Text-Fig. 53, *ax.b.*) axillary branches. The remaining bundles of the parent stele close up again and organise into the vascular cylinder of the internode above (Text-Fig. 54, *m.ax.*).

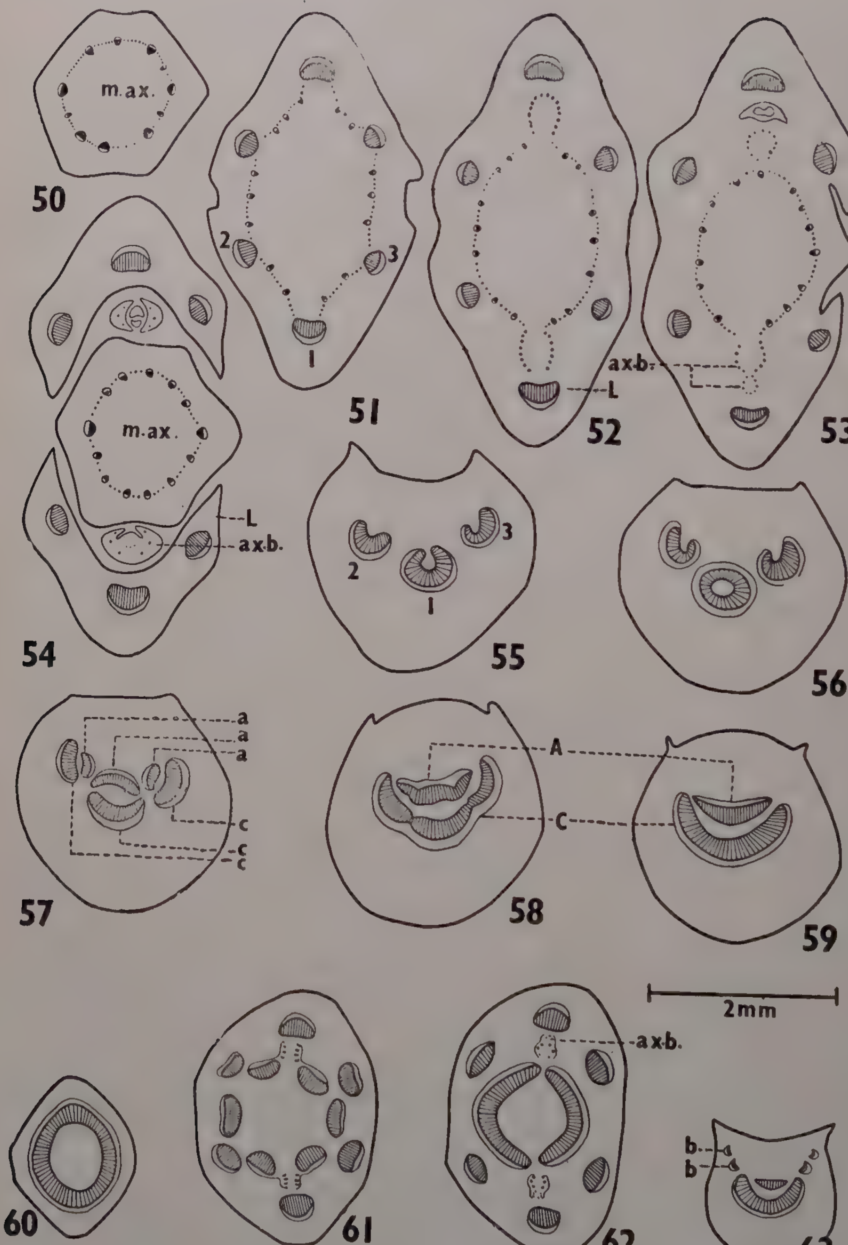
As the leaf-base separates off from the axis (Text-Fig. 54, L), the three leaf-traces come nearer and during their upward course towards the petiole expand laterally (Text-Fig. 55, 1–3) with the result that the median bundle of these three becomes completely concentric and the two lateral ones show more or less two horse-shoe shaped structures facing outward (Text-Figs. 55, 56). A little higher up, all these three bundles split up into two unequal parts each, with their xylem facing each other (Text-Fig. 57, *a, c.*). In the petiole region three larger abaxial portions of the three parent bundles fuse together laterally resulting in a crescent-shaped structure and with xylem towards the adaxial surface (Text-Figs. 58, 59, C). The remaining three small portions fuse laterally into a flat strand that has its xylem facing the crescent-shaped strand and occurs in between the free ends of the latter (Text-Figs. 58–59, A). In the petiole of *C. florida* in addition to the above structure there are two smaller bundles adaxially placed on each free end of the crescent-shaped stele (Text-Fig. 63, *b, b′*).

The vascular cylinder of the internode of *Marlea begonifolia* resembles with that of *C. capitata* in showing a continuous ring of vascular tissue dominated by xylem (Text-Fig. 64). The node is trilacunar (Text-Fig. 65, 1–3) and the median of the three bundles is represented by three (Text-Fig. 65, 1, 1′, 1″) or four small bundles. All these foliar traces while passing out into the leaf-base expand, anastomose among themselves and finally branch into many bundles of different size (Text-Figs. 66–70). They are arranged in an horse-shoe shaped pattern with a flat strand towards the adaxial side in the petiole (Text-Fig. 72, A) which is always obliquely placed at the node (Text-Figs. 70, 71, P). The remaining vascular cylinder of the internode after the departure of the leaf-traces regains its shape (Text-Fig. 71, *m.ax.*) and then contributes traces that supply the axillary branch (Text-Figs. 66–71, *ax.b.*).

Secretory ducts in this family are replaced by secretory cells that remain filled up with some dark brown substance. Druses are abundantly found in all vegetative organs.

Discussion

The Node.—Nodal structures have been studied in 23 species (Araliaceae 5, Umbelliferae 14, and Cornaceae 4). It will be recalled that these structures are fairly constant for the three families. While in the Araliaceae and Umbelliferae the nodes are multilacunar, in the Cornaceae they are trilacunar. The number of traces in the multilacunar nodes varies in different members of Araliaceae (7 in *H. nepalensis*;



TEXT-FIGS. 50–63

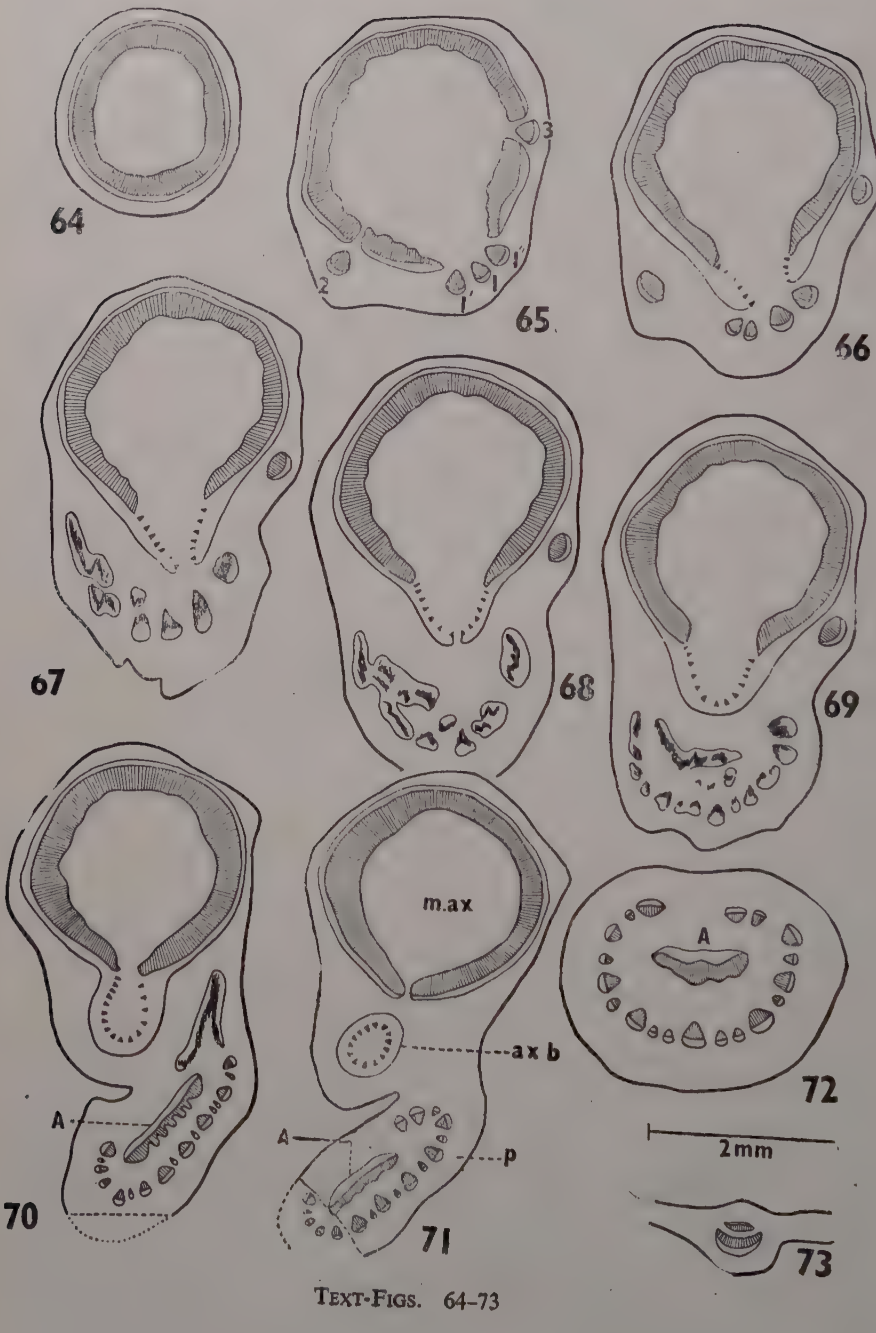
TEXT-FIGS. 50–63. *Cornus macrophylla.* Serial transverse sections of a node and petiole from base upward. Fig. 50. Shows the stele of the internode. Figs. 51–54. Show the origin of the three leaf-traces (1–3) on each side causing individual gaps in the stele of the main axis. Fig. 54. Shows two buds (*ax.b.*) in the axil of each leaf (L). Figs. 55–59. Show the behaviour of the three foliar bundles in constituting the vascular cylinder of the petiole which consists of a crescent-shaped arc (C) with a flat strand (A) facing the xylem of C. Figs. 60–63. *Cornus florida.* Serial cross-sections of a node showing a trilacunar condition. Fig. 63. A transverse section of the petiole. Note the additional two small bundles (*b*, *b'*) on each end of the crescent-shaped arc.

some 15 in *T. calyptratus* and *H. venulosum*; 17 in *P. balfouriana*; and more than 25 in *H. fragrans*) as also in Umbelliferae (5–7 in *C. asiatica*, *C. sativum* and *P. diversifolia*; 15–19, 15–17, 15 and nearly 13 in *D. carota*, *Ammi majus*, *Heracleum candicans* and *F. vulgare* respectively). Of all the umbellifers studied here *Hydrocotyle javanica* is the only species which exhibits a trilacunar node.

Sinnott (1914) after an extensive study of the nodal structure in about 165 families and 400 genera states that "in Araliaceae, which are presumably more primitive than the Umbelliferae, the number of bundles (foliar) and gaps is smaller than in the latter family, being as less as five in certain species". On the basis of the few species studied here it will not be proper for me to challenge this statement. But the fact remains that in my material it is the Araliaceae which shows the higher range.

Three significant forms of nodal structure—uni-, tri-, and multi-lacunar—forming respectively one, three or more independent gaps in the stele of the stem in angiosperms, were demonstrated by Sinnott (1914). The trilacunar nodal structure was considered by him to be the most primitive and ancient on account of its presence in majority of the primitive angiosperms and prevalence in most of the dicotyledonous plants. He derived the other two—uni- and multilacunar—conditions by reduction and amplification of the traces and gaps of the primitive trilacunar type.

For nearly 33 years Sinnott's views were generally accepted and his conclusions were used as a tool in phylogenetic considerations. But recently this concept of the primitive nodal structure has been modified to some extent by the demonstration of a fourth type of node—unilacunar with two traces. Marsden and Bailey (1955), Canright (1955), and Fahn and Bailey (1957) all have agreed on the primitiveness of this double trace unilacunar condition and the derived nature of the tri-, uni-, and multilacunar conditions in the angiosperm node. The present study does not warrant a detailed discussion of this subject here. Since there is no case of the unilacunar or double trace unilacunar condition in the species studied here, it will be presumptuous on the part of the author to attempt any comments as to which of the nodal structures is primitive and which the most advanced. But one thing needs to be pointed out. The Cornaceae, which is characterised to be the most primitive family among Umbellales, is characterised by a constant trilacunar node, while the Araliaceae and Umbelliferae,



TEXT-FIGS. 64–73

TEXT-FIGS. 64–73. *Marlea begonifolia.* Figs. 64–72. Serial cross-sections of a node from base upward. Note the continuous vascular stele of the internode in Fig. 64. Figs. 65–66. Show the trilacunar condition of the node. Note the origin of the three leaf-traces from three gaps and that the middle gap is caused by three small traces (*l*, *l′*, *l″*) which may divide further. Figs. 67–71. Show the behaviour of the foliar traces finally forming the vascular cylinder of the petiole (P) shown in Fig. 72. Note the supply of the axillary bud from the main cylinder just after the divergence of the foliar bundles. Fig. 73. Shows the structure of the midrib in the leaf.

the most advanced families of the Polypetalae, constantly exhibit multilacunar condition. This may lend some support to Sinnott's conclusion in a general sense.

It will be recalled here that the node in *C. asiatica* is multilacunar while in *H. javanica* it is trilacunar. This fact further supports author's earlier separation of *H. asiatica* into *C. asiatica* (Mittal, 1955).

It has also been pointed out by Sinnott (1914, p. 308) that the size, shape or mode of attachment of the leaf is entirely independent of the nodal structure which is extremely constant in every family of the dicotyledons. This is illustrated by the large pinnate leaves of *Fraxinus*, *Juglans* and *Daucus* which are essentially similar in size and shape and are provided respectively with one, three and many traces each, arising independently from the vascular cylinder.

But the observations recorded here lead me to think that there is some correlation between the type of nodal structure and the size, form and mode of attachment of the leaf in the three families. For example, the multilacunar nodes of Araliaceae with comparatively larger number of traces are accompanied by large compound leaves with broad sheathing bases. Umbelliferae, having somewhat smaller number of traces (multilacunar) exhibits comparatively small, simple, profusely dissected leaves with less sheathing bases. In Cornaceae, on the other hand, the nodes are trilacunar and the leaves correspondingly are small, entire, and lack sheathing bases or any stipules.

The above correlation is also apparent at the generic level. In Araliaceae, for instance, *Hedera* and *Heteropanax* are respectively characterised by about 7 and more than 25 leaf-traces. Correspondingly *Hedera* possesses small more or less entire simple leaves while in the second genus they are large pinnate decompound. In Umbelliferae too the leaves of *Daucus* and others where they are supplied by larger number of traces are larger and pinnately dissected while the simple, entire and small leaves of *Hydrocotyle*, *Centella* and *Bupleurum* are respectively supplied by 3, 5 or 7 and 9 traces each. The alternate leaves of *Marlea* among Cornaceae receive more than three traces in spite of its trilacunar nodes (the middle gap is caused by 3–4 traces together) and are bigger in size than those of *Cornus* receiving only three traces each and arranged in opposite phyllotaxy.

A very interesting feature which has been found only in the stem of *Heptapleurum venulosum* is the occurrence of a few scattered, cortical bundles. This has been explained by Joshi (1932) due to longitudinal course of leaf-trace bundles in the cortex.

The Leaf.—The leaves in Umbelliferae although apparently compound and occasionally described so (Rendle, 1925; Post, 1932; Bailey, 1949; Lawrence, 1951, etc.) are really simple in majority of cases, the lamina being continuous over the rachis.

During the present investigations some interesting features in the anatomy of the petioles of the Araliaceae have been observed. Firstly, the vascular bundles in the base of the petioles are scattered and variously oriented. Secondly, in the upper portion of the petioles there are two rings of vascular bundles of which the inner medullary ones are peculiarly and inversely oriented (absent in *Hedera* and *Polyscias*). These features are constant in the species of *Heteropanax*, *Heptapleurum* (*see* also Joshi, 1932) and *Tupidanthus*. Similar medullary bundles in the petioles of about 30 genera of Araliaceae have also been recorded by Viguier (1906).

Worsdell (1915, 1919) considered the presence of medullary bundles in the stem of flowering plants to be a primitive character which is retained by monocotyledons and lost by dicotyledons. Joshi (1932) states that while Worsdell's theory can easily explain the absence of medullary bundles in the stem and their presence in petioles, it fails to explain the condition found in *Heptapleurum venulosum*, *i.e.*, presence of the medullary bundles in petioles and cortical bundles in the stem.

Jeffrey (1917), however, explains these medullary bundles as a result of elaboration to meet greater physiological necessities and the peculiar arrangement being enforced by lack of adequate amount of space. This appears to be more convincing explanation than that of Worsdell (*see* also Joshi, 1932).

It will be recalled that these medullary bundles in the Araliaceae are inversely oriented. This feature also deserves some comment. Worsdell explains the inversion of these bundles by assuming their derivation from amphivasal concentric bundles by reduction. This interpretation is challenged by Joshi (1932) who has observed the derivation of these bundles in *Heptapleurum venulosum* from normally oriented bundles through rotation of 180°.

Umbellifer leaves are generally described as petiolate but the present author is led to believe that a morphologically true petiole lacks in the family, and that the leaves are thus sessile rather than petiolate. This idea is supported by the fact that in most of the cases it is the sheathing leaf-base which gradually narrows upward and finally merges into the leaf-blade remaining flattened throughout. The leaf-traces also remain arranged in a crescent-shaped arc and finally disperse into the lamina. Sometimes this leaf-base folds its margin adaxially and gives a false appearance of a cylindrical petiole. In some cases, *e.g.*, *Centella* and *Daucus* where the 'petiole' has respectively a superficial or a deep adaxial groove it is seen that the lamina continues over the 'petiole' along the margins of the groove for a longer distance and thus in these genera the leaves are sessile or may be shortly petiolate.

The Secretory Ducts.—While the secretory or the oil ducts are the characteristic features of Araliaceae and Umbelliferae, they are absent in Cornaceae. They generally occur in close association with the phloem of the vascular bundles. To explain their constant position it was suggested that these ducts collect the useless waste products which travel with the important food material from active metabolic stations to the phloem strands. But this notion does not accord with the chemical character of the contents of these ducts. Later on Stahl and Kniep (quoted from Haberlandt, 1914) on the basis of such a study have suggested that these products protect the vascular strands from the attack of the noxious animals by their chemical action. Aromatic oils produced in the Umbellifers also perhaps serve the same purpose.

Phylogenetic Considerations.—Table II gives some important characters which throw some light on the interrelationships of the families generally included in this order.

TABLE II

Characters	Araliaceae	Umbelliferae	Cornaceae
1. Arborescent (+) or herbaceous (—)	+	—	+
2. Leaves opposite (+) or alternate (—) or both (±)	—	—	±
3. Leaves simple (+) or compound or much dissected (—)	—	—	+
4. Sheathing base or stipules (+) or none (—)	+	+	—
5. Node multilacunar (+) or trilacunar (—)	+	+	—
6. Leaf petiolate (+) or sessile (—) or both (±)	+	±	+
7. Medullary bundles in petioles present (+) or absent (—)	+	+	—
8. Secretory ducts present (+) or absent (—)	+	+	—

The phylogenetic relationships of these families will be dealt in detail at a later stage. However, in view of some common features,

e.g., presence of sheathing leaf-base, compound or much dissected leaves, medullary bundles in petioles of certain genera, secretory ducts, multilacunar nodes found in Umbelliferae and Araliaceae, their natural relationship becomes clear. Cornaceae, on the other hand, seems to stand aloof from these two families in certain important respects, *e.g.*, presence of trilacunar nodes, absence of secretory ducts, medullary bundles in petioles and sheathing leaf-bases.

It may be pointed out in this connection that the exclusion of Cornaceae from Umbellales was suggested earlier by Sinnott (1914) and Hoar (1915) from a study of node and wood anatomy respectively. Recently Rodriguez (1957) has also arrived at a similar conclusion.

Summary

The present study includes 23 species of which 5 belong to Araliaceae, 14 to Umbelliferae and 4 to Cornaceae.

The nodal structure is multilacunar in Araliaceae and Umbelliferae, and trilacunar in Cornaceae which is believed to be primitive in this respect.

A correlation between the type of nodal structure and the size, form and mode of attachment of the leaf in the three families has been brought out. For instance, multilacunar nodes with larger number of traces are accompanied by large compound leaves with broad sheathing bases, while the trilacunar ones are associated with small, simple leaves with no sheathing leaf-bases.

Medullary bundles have been reported in the petioles of certain genera of Araliaceae. Few cortical bundles are also seen in the stem of *Heptapleurum venulosum*.

Leaves in Umbelliferae are sessile or shortly petiolate.

Secretory ducts are present in Araliaceae and Umbelliferae generally associated with the phloem of the vascular bundles. Cornaceae lacks these ducts but possesses plenty of secretory cells.

Separation of *Hydrocotyle asiatica* into *Centella asiatica* is further justified on the basis of the nodal structure.

Retention of the families Umbelliferae and Araliaceae in the Umbellales and the exclusion of the Cornaceae from the latter is justified.

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ROOT APICAL ORGANIZATION IN MONOCOTYLEDONS—MUSACEAE

By S. K. Pillai and (Mrs.) Ambuja Pillai

Department of Botany, Birla College, Pilani, Rajasthan

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It is well known that the root apex has not received the same amount of attention from anatomists as the shoot apex. The state of chaos which exists in our knowledge of root apices has been emphasized by authors like Eames and MacDaniels (1947), Popham (1952) and Esau (1953). Foster (1949) has pointed out that investigations on a wide variety of plants should aid in clarifying the present confused state of terminology and interpretation with reference to root apices. Studies of Janczewski (1874), Treub (1876) and others in the last century and of Guttenberg (1940, 1947), Clowes (1950–59) and others in the present century have not enabled us to put forward any views regard ng histogenesis and organization which is widely accepted. Mainly the theories put forward to explain the organization of shoot apices are being applied to root apices also. Unless more detailed studies are undertaken on many plants it would be difficult to arrive at any generalizations. This has been the incentive for these investigations, part of which is being reported here.

Materials and Methods

Root apices of the following species were fixed on the spot in F.A.A. :

Musa paradisiaca Linn., *Ravenala madagascariensis* Sonn., *Musa sapientum* Linn., and *Heliconia illustris* Ker-Gawl.

They were refixed in the laboratory in Randolph's modification of Navaschin's fluid (CRAF) for 18–24 hours, washed four to five times in succession, and for 15–20 minutes each time, in 70% alcohol following Johansen (1940), upgraded, cleared in xylol and imbedded in paraffin. Sections were cut at 7–10 μ thickness and the following staining schedules were tried: Iron alum haematoxylin (with 7·5% glacial acetic acid added for effecting quick maturity and good differentiation), pyronin and methyl green and safranin and fast green. Of these the first two schedules brought out the cyto-physiological state of the cells at the tip and the first and third the structural organization better.

Observations

These are based on the structural configuration on the one hand and the cyto-physiological state of the cells on the other.

A. Structural Organization

Under lower magnification the plerome appears to be separate, but critical examination under higher magnification showed this to be illusory and only a common group of initials is found, from around which the meristems of the root-cap, dermatogen, periblem and plerome arise (Text-Figs. 1, 5, 7 and 8). Therefore, there can be said to be a *pseudo-plerome* present in these.

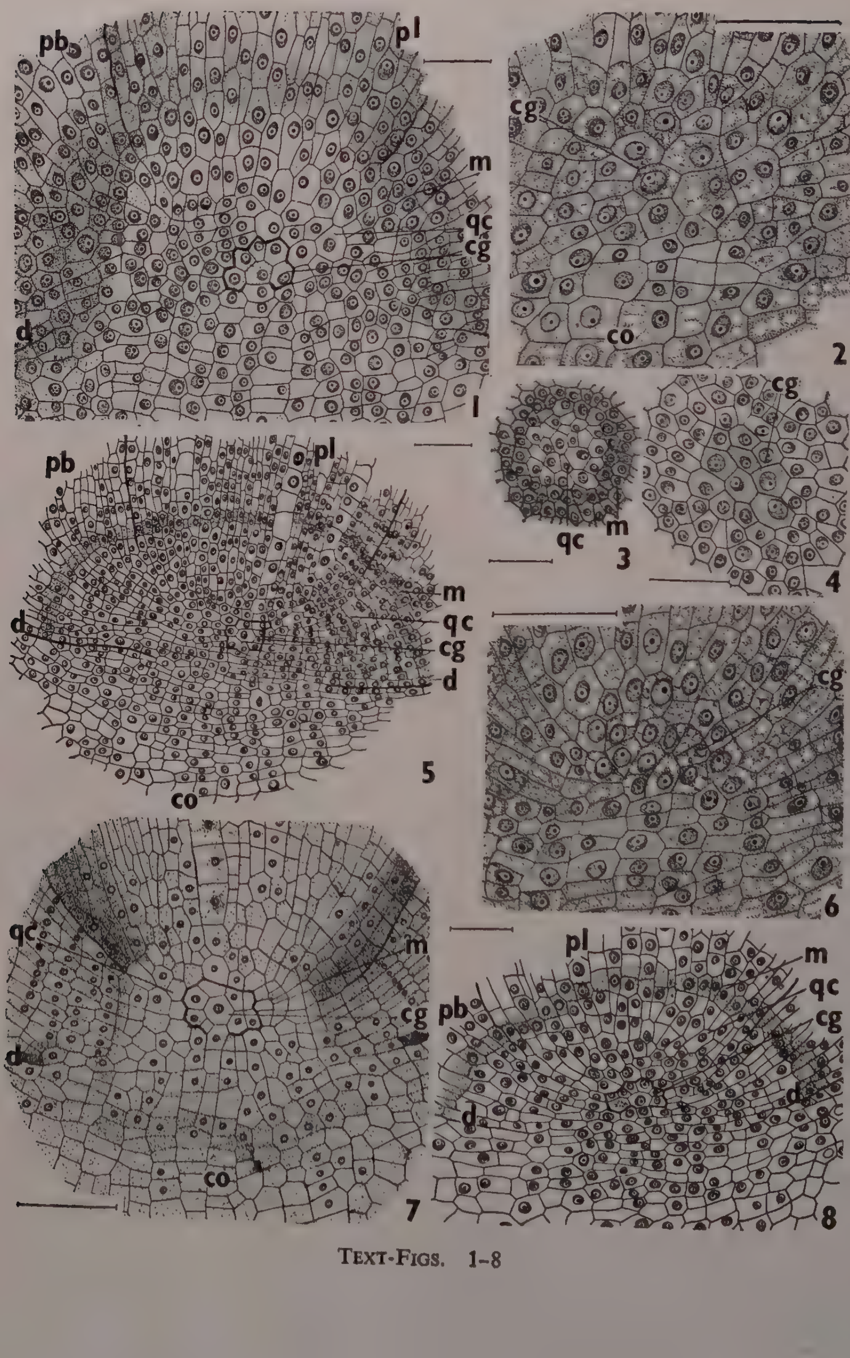
Root-cap.—Though the root-cap is not separate from the root body, this portion can be distinguished by the analysis of the cell complexes into a central region and a peripheral region. In the central region the cells are arranged in longitudinal files of superimposed tiers constituting the columella whereas in the latter the cells are arranged in oblique files curving from the flanks towards the columella. These files exhibit the T-type divisions at the flanks with the capital of the T pointing backwards enabling the peripheral region of the cap to widen out to the front. When we trace the columella to the centre of the common group of initials we are able to distinguish the meristem concerned with its formation. This meristem is characterised by its cells dividing mainly transversely and not contributing to the peripheral region. It is being named as the *columellogen.*

When the columella is traced towards the inside, there is found at the head of the middle row a big cell or two surrounded by a group of slightly smaller cells (Text-Figs. 1, 4, 5, 7 and 8). This is designated here as the *central group*. Around this are the cells of the common group which are, as mentioned above, not differentiated into any structural histogens except the columellogen towards the outside.

Histogens of the root body.—From the brim of the common group of initials arise the columellogen to the front and the peripheral region on the flanks. The dermatogen also arises to the flanks inside the peripheral region of the cap and the periblem and plerome arise at the middle on the inside.

Dermatogen.—This separates out from the common group of initials on the flanks. Once distinctly established, its cells, composed of a single layer, divide only anticlinally. Near the tip the cells of this histogen are long, vacuolated and with lightly stained cytoplasm while some distance behind, due to repeated divisions, they become short and narrow and appear like a stack of coins. Also they are not prominently vacuolated and have densely staining cytoplasm. The term dermatogen is applied to this histogen in a restricted sense because, though it does not have an independent origin as first enunciated by Hanstein (1868) in his classical histogen theory, it is concerned only with the formation of the epidermis once it has separated out and become distinct.

Periblem.—This term is also used in a limited sense and refers to the initials of the cortex. The initials of the periblem can be distinguished by their location in median longisections between the cells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TEXT-FIGS. 1–8

TEXT-FIGS. 1–8. Fig. 1. *Heliconia illustris.* A median longisection through the tip of the root body showing common group of initials with the central group (*cg*) in the middle at the head of the columella. The dermatogen (*d*), periblem (*pb*) and plerome (*pl*) can be seen becoming distinct around the common group of initials. The quiescent centre (*qc*) can be seen in the middle surrounded on the side of the root body like an arch by the meristematic zone (*m*) (the cells of which are more deeply stippled). Fig. 2. *Musa paradisiaca.* A portion of the central region of the common group of initials in median longisection, enlarged to show the central group (*cg*) with the cells of the columella proceeding towards the front. Note the cyto-physiological state of the cells. Fig. 3. *Ravenala madagascariensis.* A transection passing through the quiescent centre (*qc*) surrounded by the meristematic zone (*m*). Fig 4. *Heliconia illustris.* A transection showing the central group (*cg*) and a few cells of the quiescent centre around it (semidiagrammatic). Fig. 5. *Musa paradisiaca.* A diagrammatic sketch of the median longisection of the apical portion of the root body showing the common group of initials with the central group (*cg*) in the centre and the dermatogen (*d*), periblem (*pb*) and plerome (*pl*) separating around it. The meristematic zone (*m*) surrounds the quiescent centre (*qc*) like an arch. Fig 6. *Musa sapientum.* The central portion of the common group of initials, enlarged to show the cyto-physiological state of the cells. The central group (*cg*) can be seen in the middle at the head of the columella. Fig. 7. *Musa sapientum.* A median longisection of the apical region of the root body showing the common group of initials with the central group (*cg*) and the dermatogen, periblem and plerome separating out around it. The central group can be seen at the head of the columella (*co*). *qc*. Quiescent centre (lightly stippled); *m*, Meristematic zone (deeply stippled). Fig. 8. *Ravenala madagascariensis.* A median longisection passing through the apical region of the root body showing the common group of initials with the central group (*cg*) in the middle. The dermatogen (*d*), periblem (*pb*) and plerome (*pl*) can be seen becoming distinct around the common group. *m*, Beginning of the meristematic zone (stippled) around the quiescent centre (*qc*). (All scales,—50 μ).

of the dermatogen outside and the pericycle inside. It is comparatively broad being composed of many superimposed layers of cells near the common group of initials. They exhibit T divisions, with the capital of the T pointed forward, enabling the periblem to widen out (Text-Fig. 7). After this the cells divide mainly transversely. Here also the cells just surrounding the *central group* are lightly stained and vacuolated while some distance behind this region, they are deeply stained and do not show prominent vacuolation.

Plerome.—These initials give rise to the pericycle, vascular elements and pith. The pericycle is composed of one layer of cells which have deeply staining cytoplasm and which retain their meristematic activity to a longer distance behind the tip, long after the adjoining cells have lost it.

The medullary region in the centre of the roots of the two species of *Musa* and of *Ravenala madagascariensis* exhibits scattered vascular bundles. They are referred to as medullary bundles.

B. Cyto-physiological organization

Notwithstanding the structural organization described above, it is possible to distinguish two zones at the tip of the root proper based on cyto-physiological grounds.

(1) *The Quiescent Centre.*—At the tip of the root body, which does not include the root-cap, could be distinguished a group of cells which have (1) cytoplasm which is lightly stained with haematoxylin

and pyronin and methyl green (Text-Figs. 1, 5, 7 and 8), (2) vacuolation noticeable in most cells (Text-Figs. 2 and 6), (3) smaller nucleoli (Table II) and (4) where frequency of divisions is less (Table I). This group of cells is in the shape of a cup with the broader part towards the front of the root. This zone of cells in a state of comparative repose has been named by Clowes (1956 *a* and *b*; 1958 *a*) as the *quiescent centre.* This embraces and includes cells belonging to the various structural histogens after they are distinguishable and the common group of initials in the centre.

TABLE I

Showing the number of cells in the quiescent centre and the meristematic zone, the number of dividing cells and the percentage of dividing cells (as seen in each transection)

Plant species	Quiescent centre			Meristematic zone		
	Total No. of cells	No. of dividing cells	Percentage	Total No. of cells	No. of dividing cells	Percentage of division
Musa sapientum ..	49	2	4·08	139	46	33·1
	54	3	5·5	102	29	28·4
	49	2	4·08	100	29	29·0
	47	1	2·12	98	29	29·5
	50	2	4·0	100	29	29·0
Musa paradisiaca ..	91	1	1·09	120	25	20·83
	78	4	5·12	94	27	28·72
	86	3	3·48	116	29	25·00
	91	5	5·49	144	40	27·77
	76	3	3·94	94	25	26·59
Ravenala madagascariensis	108	3	2·78	133	25	18·79
	92	5	5·43	123	33	26·82
	114	7	6·14	1[illegible]4	27	20·14
	92	4	4·34	124	34	27·41
	102	2	1·96	130	24	18·46
Heliconia illustris ..	94	2	2·12	105	15	14·28
	105	4	3·80	140	18	12·85
	92	1	1·08	150	20	15·00
	100	2	2·00	110	15	13·63
	102	3	2·94	130	18	13·84

(2) *The Meristematic Zone.*—Surrounding the quiescent centre excepting on the side of the root-cap, are found cells which have (1) cytoplasm deeply stained with haematoxylin and pyronin and methyl green (Text-Figs. 1, 5, 7 and 8); in transections these cells surround the quiescent centre (Text-Fig. 3 and Plate XIII, Figs. 1 and 2), (2) smaller vacuoles, (3) bigger nucleoli (Table II) and (4) greater frequency of division figures (Table I). This zone seems to be the one actually

TABLE II

The areas in sq. μ of the cell, nucleus and nucleolus in the quiescent centre and meristematic zone and the respective nucleolus/nucleus and nucleus/cell ratios

(Mean of 20 determinations)

Plant species	Quiescent centre				
	Cell	Nucleus	Nucleolus	Nucleolus/Nucleus	Nucleus/Cell
Musa paradisiaca ..	75·11 ±14·54	12·54 ±3·75	0·5784 ±0·1246	4·61	16·7
Musa sapientum	78·84 ±20·49	14·36 ±2·89	0·6099 ±0·1230	4·24	18·21
Ravenala madagascariensis	41·84 ±8·88	14·42 ±5·36	0·3481 ±0·0788	2·41	34·47

Plant species	Meristematic zone				
	Cell	Nucleus	Nucleolus	Nucleolus/Nucleus	Nucleus/Cell
Musa paradisiaca	64·00 ±21·88	13·00 ±4·18	1·2420 ±0·1715	9·55	20·31
Musa sapientum	66·19 ±16·94	14·83 ±3·60	1·5838 ±0·3454	10·75	22·40
Ravenala madagascariensis	33·96 ± 8·89	8·62 ±1·79	1·1099 ±0·2746	12·88	25·37

concerned with the production of new cells, that is, the actual meristematic zone. It has, therefore, been designated in these discussions as the *meristematic zone*.

(3) *Comparison between the Quiescent Centre and the Meristematic Zone.*—A count of the total number of cells and the number of dividing cells (where the nuclei show any stage of mitosis) was made in these two zones and the results are presented in Table I. The percentage of dividing cells in the total number of cells was also calculated. These show that the cells of the quiescent centre are in a state of comparative repose, there being very low percentage of division.

The respective areas of the nucleolus, nucleus and cell were measured from some of the cells of the quiescent centre and the meristematic zone around it in some of these plants. Care was taken to select cells

with one nucleolus in their nuclei (Table II). The nucleoli and nuclei are smaller in the cells of the quiescent centre. The proportions of the area of nucleolus/nucleus and nucleus/cell were also calculated in these cases (Table II). These proportions are smaller in the cells of the quiescent centre. These and the responses to staining with pyronin and haematoxylin indicate that there is lesser synthesis of nucleic acids. Caspersson and Schultz (1939), Brachet (1940) and (1952) and Clowes (1956 *a* and *b*) have also shown by other methods that there is lesser synthesis of nucleic acids in the cells in a quiescent state.

Another feature in support of the quiescent state of the cells at the tip and the meristematic state behind the tip is shown by the cells of the dermatogen which appear long and broad at the quiescent centre and short and narrow and arranged like a stack of coins at the meristematic zone.

When transections passing through the quiescent centre and the meristematic zone are examined, there is found in the centre a group of lightly stained cells surrounded by an annular zone where the cells have deeply stained cytoplasm and no vacuolation (Plate XIII, Fig. 1). A little behind this region almost all the cells appear more or less similar with dense cytoplasm (Plate XIII, Fig. 2).

One important feature of the quiescent centre which should be mentioned here is that it is not a structural zone like the histogens but one which can be distinguished by the physiological and cytological state of the cells. It includes the structural histogens of the root body. On the other hand, there is no such demarcation between the quiescent centre and the meristematic zone around it. It is found that the cells of the former gradually transcend into the latter and merge with it.

The distance at which the vascular elements appear behind the root-tip and the distance at which the first mature phloem elements appear were measured (Table III). The phloem elements mature about 165–400 μ behind the tip of the root body.

TABLE III

Showing the levels of origin of vascular elements and the level of the mature phloem, in μ behind the root-tip

Plant species	Level of origin of			Level of appearance of mature phloem
	Metaxylem	Protoxylem	Phloem	
Musa paradisiaca ..	20–25	50– 55	45– 50	160–165
Ravenala madagascariensis ..	80–85	100–105	80– 85	265–270
Heliconia illustris ..	45–50	95–100	95–100	400–410

Discussion

Students of root anatomy are aware of the woeful state of confusion existing in our knowledge of root apical organization in general. Unlike the shoot apex which is terminal and can, therefore, be approached directly, the root apex is subterminal and hence its study is more complicated, though there is a widespread feeling that the study of root apices is simpler because of the absence of lateral appendages like the leaf and the bud.

The structural organization described above falls under the fifth type of Haberlandt (1914) and fourth type of Hayward (1938) and Esau (1953). These authors and others like Janczewski (1874) in the last century do not consider such a type to be found among monocotyledons at all, though Mann (1952) has described it in *Allium sativum*, which Esau quotes.

Treub (1875) has mentioned *Musa ornata* under the type with two groups of tissue initials, one independent plerome and the other giving rise to the cap, epidermis and cortex. But this is not found in the two species of *Musa*, which were investigated here, though the pseudo-plerome gives such an impression. Deshpande (1956), while investigating the root apices of a number of members of Liliaceae and Amaryilldaceae, found this type of organization in the arboreal and semi-arboreal species *Dracaena angustifolia* L. and *Aloe vera* Linn. Mulay and Panikkar (1956) have found a similar organization in the roots of the terrestrial orchids *Cypripedium speciosum* L., *Peristeria elata* Hook. and *Phajus wallichii* Lindl. Thus, this type seems to be common enough among monocotyledons and particularly the arboreal and less evolved members. Musaceae is also considered the least evolved among the families of the Scitamineae and its members reported upon here exhibit this type of organization, whereas members of the more highly evolved families of this order, *viz.*, Zingiberaceae, Cannaceae and Marantaceae, show a different type of organization with discrete initials, which will be described in some forthcoming reports.

Under higher magnification there could be distinguished a prominent cell or two in the centre of the common group of initials located at the head of the columella, with a group of smaller cells around it (Text-Figs. 1, 5, 7 and 8). Guttenberg (1940, 1947) has postulated that in the root apices there is a "central cell" which completes in most cases the middle columella row (Schade and Guttenberg, 1951). Recently Guttenberg *et al.* (1954 *a* and *b*) have, as a result of their study of embryogeny, modified their view and consider the central cell to be active only in the embryo stage. This gives place to a group of initials as the root grows.

The "initial group" hypothesis of Brumfield (1943) also cannot be applied here, as he postulates the presence of a group of *three* cells in the centre responsible for the initiation of all the meristems of the root. Such a group of cells is not found in any of these roots. Clowes (1959 *b*) gives reasons for rejecting Brumfield's conclusions about the

number of initials in normal roots. Here, the prominent cell or two with the surrounding group of a few cells can be considered as the initial group; but this is a much bigger group than that postulated by Brumfield and so is called the *central group*.

Though it is possible to make out some type of structural configuration, these studies point to the fact that the cyto-physiological state of the cells at the apex has a very important bearing on regeneration and histogenesis and the interpretation of the root apical organization. The cells at the extreme tip of the root body exhibit the cyto-physiological characteristics pointed out earlier. Also, the quiescent centre is of varying sizes, being smaller in thin and young roots and bigger in thicker and mature roots (Table I). This group of cells includes the cells of the common group of initials in the centre and the structural histogens of the root body after they are distinguishable, though not of the root-cap. It is cup-shaped with the broader part towards the root-cap. Clowes (1956 *a* and *b*, 1958 *a* and *b*) has found this group of cells to have reduced synthesis of nucleic acids as a result of studies with pyronin on one side and with labelled compounds on the other. The characteristics of the cells show that they are in a state of comparative repose, because of which Clowes (1956 *a*) has named it the "quiescent centre". A perusal of the literature shows that this state of the cells is not recognized by earlier workers, though sporadic references to some feature or other has been made by Schüepp (1926), Zirkle (1932), Dermen and Bain (1944) and others.

Studies reported here and others to follow show that the cells at the extreme tip, *i.e.*, where the initials and their immediate derivatives are located are in a state of comparative repose as is evident from the lesser frequency of divisions (Table I). This is further supported by the cyto-nuclear and nucleolus/nucleus ratios (Table II) and the staining reactions of the cells of the two regions. The authors also call this group of cells as the "quiescent centre" following Clowes (1956 *a*). The cells surrounding this and which appear to be the seat of actual meristematic activity have been continued to be called by Clowes (1959 *a*) by the older term "promeristem". Clowes (1950, 1953) defines the promeristem "to mean the collection of initials within the meristem from which all future tissues are derived". This definition was given before the postulation of the quiescent centre by him. He, in 1959 *a*, still uses the same term to mean "the collection of cells in the form of an arch lining the quiescent centre, where actual histogenesis occurs", *i.e.*, excluding the quiescent centre. There is, naturally, a confusion brought about. So, to avoid this the new expression "*meristematic zone*" is being used.

This recalls the postulation of Plantefol (1947) of an *anneau initial* at the shoot tip and that of Buvat (1952) of a *meristeme d'attente*. An examination of Plate XIII, Fig. 1 will reveal that there is a very close similarity between the postulates of the Plantefol school and what is postulated here, the quiescent centre being equivalent to the *meristeme d'dttente* and the meristematic zone to the *anneau initial*.

A possible explanation for the cells at the extreme tip going into quiescence is that they do not get sufficient nutrients. The mature phloem elements, which supply the metabolites required for the cells in an active state, stop about 200 μ short of the tip of the root body (Table III), after which they will have to move forward by diffusion. In this passage they are utilized quickly by the cells of the meristematic zone and the cells farther forward are deprived of these substances and hence go into repose.

Summary and Conclusions

The structural apical organization of four species of Musaceous plants shows that there is a common group of initials from around which the various histogens originate. In the centre of this could be distinguished a smaller group of prominent cells which is designated as the *central group*.

The study of the cyto-physiological state of the cells is found to be very important in interpreting the apical organization. This study of the cyto-physiological state shows that there are, at the tip of the root body excluding the root-cap, some cells in a quiescent state. Behind them as seen in longisections, the cells are in a more active state and constitute the real histogenetic region, named here the *meristematic zone*. In transections the latter surrounds the former recalling the postulate of the Plantefol school. The characteristics of the quiescent centre and meristematic zone are described. A possible explanation for the state of quiescence is put forward.

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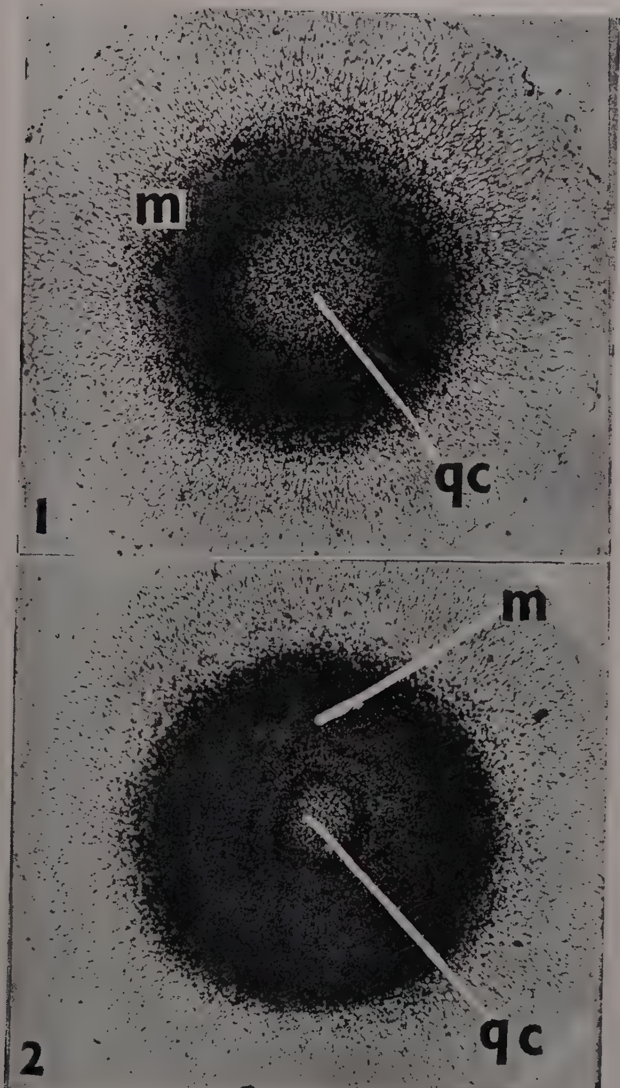

FIGS. 1-2

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EXPLANATION OF PLATE XIII

FIG. 1. *Musa paradisiaca*. A transection passing through the brim of the cup-shaped quiescent centre (*qc*), surrounded by the meristematic zone (*m*).

FIG. 2. *Musa paradisiaca*. A transection of the root region just behind that shown in Fig. 1. Note the formation of the plerome and the smaller diameter of the quiescent centre, being the bottom of the cup (*qc*). Note also that most of the cells are with deeply stained cytoplasm, showing that the meristematic zone (*m*) covers the quiescent centre like an arch. (Both Figs. × 60.)

STUDIES ON PECTOLYTIC ENZYME SYSTEM OF *RHIZOCTONIA SOLANI* KÜHN.

III. Pectinesterase and Polygalacturonase

By K. B. Deshpande*

Imperial College, London

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Introduction

In addition to finding out that secretion of pectolytic enzymes by plant pathogens is a part of mechanism of their pathogenicity, the characterisation of these enzymes and analysis of their effect on host tissue have been now recognised as a major study in plant pathology. In view of this fact many workers from Imperial College (Wood, 1955) have reported that culture filtrates of many plant pathogens containing protopectinase, almost always contain other pectolytic enzymes like pectinesterase, polygalacturonase and depolymerase. After investigating the production and properties of protopectinase (Deshpande, 1960 *a*, *b*), the culture filtrates of *Rhizoctonia solani* were also examined for the presence of other pectic enzymes and the results obtained are reported in this paper.

Material and Methods

In the present investigation a strain of *R. solani* isolated from damped-off swede seedlings was used. The fungus was cultured in the liquid medium of the following composition:

Glucose 0·125%, peptone 0·25%, KH_2PO_4 0·1%, $MgSO_4.7H_2O$–0·05%, yeastrel 0·02%, Citrus Pectin (California Fruit Growers' Exchange) 2·0% and 1 ml. of a minor element mixture of 1% of each of the chemicals, $FeSO_4.\ 7H_2O$, $CuSO_4.5\ H_2O$, $ZnSO_4 \cdot 7H_2O$ and $MnSO_4$.

25 ml. of the medium was poured into 10 oz. medicinal flats, sterilized, inoculated and then incubated at 25° C. for 7 days. The fluid from a number of cultures were then mixed, passed through muslin and obtained cell-free by centrifuging at 8,000 r.p.m. for 10 minutes. This culture filtrate was used to study the activity of various pectolytic enzymes.

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* At present: Dept. of Botany, Osmania University, Hyderabad Deccan, India.

Pectin esterase (PE)

Pectinesterase catalyses the hydrolysis of methylester groups (OCH_3) of pectinic acids and pectins and liberate free carboxyl groups (COOH), thus converting them to pectic acids (polygalacturonic acids) and the estimation of these carboxyl groups thus split off form the basis of a method widely used for measuring PE activity (Kertesz, 1937; Colowick and Kaplan, 1955). Therefore this method was employed in the following way:

Washed citrus pectin and NaCl were dissolved in water to give 500 ml. of a solution containing 1% pectin and 0·1 M NaCl with a pH value of 3·0. Aliquots of 25 ml. were placed in glass-stoppered Erlenmeyer flasks and 0·5 ml. of the indicators, bromophenol blue, bromocresol green, or bromothymol blue were added and the pH values were adjusted with 0·1 N NaOH to 3·5, 5·0 and 7·0 respectively. Five ml. of crude, dialysed or autoclaved enzyme solutions were adjusted to the appropriate pH value and added to the pectin solutions. The mixtures were stirred during the experiment, and changes of colour were corrected periodically by adding known volumes of 0·1 N NaOH (Table I). The reaction mixture was incubated at 25° C.

TABLE I

Quantity of 0·1 *N NaOH and the time*

Time (in hours)	Crude			Dialysed			Autoclaved		
	3·5	5·0	7·0	3·5	5·0	7·0	3·5	5·0	7·0
½	0	0·4	0·2	0·2	0·1	0·0	0·0	0·0	0·0
1	0	0	0	0	0	0	0	0	0
1½	0·2	0·5	0	0	0·1	0	0	0	0
2	0	0	0	0	0	0	0	0	0
2½	0	0	0	0	0	0	0	0	0
3	0·4	0·3	0	0	0·3	0	0	0	0
Total	0·6	1·2	0·2	0·2	0·5	..	..	..	..
15	0·9	1·7	0	0·5	0·8	0·1	0	0	0

At the end of 3 hours the PE activity was calculated according to the following formula:

$$PE = \frac{\text{Total No. of ml. of } 0\cdot1 \text{ N NaOH} \times 3\cdot1}{\text{Vol. of enzyme}} \Big/ \text{unit time}$$

(Kertesz, 1937) and the results are given in Table II.

TABLE II

PE activity of culture filtrates of R. solani

Enzyme	pH	N/10 NaOH added (ml.)	*PE units
Crude ..	3·5	0·6	12×10^{-2}
" ..	5·0	1·2	24×10^{-2}
" ..	7·0	0·2	4×10^{-2}
Dialysed ..	3·5	0·2	4×10^{-2}
" ..	5·0	0·5	10×10^{-2}
" ..	7·0	0·0	..
Autoclaved	3·5, 5·0, 7·0	..	..

* The enzyme activity is expressed as the milligrams of OCH_3 liberated in one hour per millilitre of enzyme solution.

The data indicate that PE activity was considerable in filtrates from cultures of *R. solani*. PE was most active at pH 5·0, about half as at pH 3·5, as at pH 5·0 and about a sixth as active at pH 7·0. In addition, crude preparations showed more PE activity than dialysed ones, although optimum pH for both was the same. This result is rather interesting when compared to the pectic enzyme systems of *Pythium debaryanum* (Gupta, 1954) and *Fusarium moniliforme* (Singh and Wood, 1956) as both do not produce pectinesterase. Jarvis (1953) has reported that *Botrytis cinerea* does produce pectinesterase and therefore this result is comparable with that of *B. cinerea*.

Polygalacturonase activity (P.G.)

This enzyme hydrolyses the pectic acids to free D-galacturonic acid. Various methods are used to estimate the PG activity. Two of them are employed and described here to estimate the PG activity of culture filtrates of *R. solani*.

(1) *Measurement of reducing groups.*—The PG activity of culture filtrates was measured by the hypo-iodite method of Willstaffer and Schudel, modified by Jansen and McDonnell (1945). It consists in determining the increase in reducing groups (CHO) which are released during hydrolysis of pectic substances by PG.

The citrus pectin (9·5% OCH_3) and sodium polypectate were washed in acidified alcohol (95 ml. of 80% alcohol + 5 ml. concentrated HCl), and then in 95% alcohol and dried at 30° C. One per cent. solutions were prepared and 25 ml. aliquots of each were adjusted to pH 3·5 and 6·5. Crude and dialysed enzymes were also adjusted to these pH values. Veronal buffers (Michaelis, 1930) at pH 3·5 and 6·5 were used to prevent drift of pH during the experiment. The following were the final mixtures:

a	ml.	*b*	*ml.*
1% of pectin solution at pH 3·5 or 6·5	25·00	1% Na-polypectate solution at pH 3·5 or 6·5 ..	25·00
Veronal buffer	5·00	Veronal buffer ..	5·00
Crude or dialysed enzyme solutions at pH 3·5 or 6·5	10·00	Crude or dialysed enzyme solutions at pH 3·5 or 6·5	10·00
Distilled water	10·00	Distilled water	10·00
Total ..	50·00	Total ..	50·00

The mixtures were incubated at 25° C.

The reducing values of 2·5 ml. samples of these mixtures were determined at 0 hour, *i.e.*, immediately after adding the enzyme and at 2, 8, 24 and 48 hours later. Toluene was added to the mixtures after 8 hours to prevent contamination. 0·9 ml. of 1 M Na_2CO_3 and 2·5 ml. N/10 I_2 were added to the sample, which was left for 20 minutes. The reaction mixture was then acidified with 1·0 ml. of 2N H_2SO_4 and the residual iodine was titrated with N/100 $Na_2S_2O_3$. The increase in the reducing power of the samples as a result of enzyme action is expressed in Table III in terms of ml. N/100 $Na_2S_2O_3$. The data of another experiment are also included in Table III (Sample *b*).

These results show that filtrates from cultures of *R. solani* contain a PG which degrades both pectin and sodium polypectate. Another feature of PG activity was that the crude enzyme was more active than dialysed preparations. The dialysed preparation, rather surprisingly was more active at pH 6·5 than at pH 3·5 when pectin was used. But with sodium polypectate the activity was similar or a little

TABLE III

PG activity on solution of pectin and sodium polypectate

Sample	Time of sample (hr.)	0·5% of pectin solution				0·5% sodium polypectate solution			
		pH 3·5		pH 6·5		pH 3·5		pH 6·5	
		Crude enzyme	Dialized enzyme	Crude enzyme	Dialysed enzyme	Crude enzyme	Dialysed enzyme	Crude enzyme	Dialysed enzyme
1 *a*	0	0	0	0	0	0	0	0	0
b	..	0	0	0	0	0	0	0	0
2 *a*	2	3·1	0·7	2·1	0·8	4·9	1·7	5·2	2·1
b	..	5·6	1·9	1·5	0·6	4·4	3·5	2·7	1·5
3 *a*	8	5·8	1·2	3·7	1·7	6·8	3·4	5·5	3·0
b	..	9·3	4·3	4·7	4·4	6·5	5·6	3·3	2·1
4 *a*	24	7·4	2·2	6·3	5·5	8·2	3·9	5·9	3·5
b	..	12·2	5·8	8·6	6·8	8·1	5·6	4·3	3·4
5 *a*	48	9·0	3·9	8·6	7·7	8·1	4·8	6·6	4·2
b	..	13·5	6·2	11·4	9·0	9·1	7·0	6·9	4·8

more at pH 3·5 than at pH 6·5. The activity of the crude enzyme on pectin was similar at both pH values but with sodium polypectate the activity was similar or a little more at pH 3·5 than at pH 6·5.

The activity of PG in relation to rate of hydrolysis and substrates also showed some striking results. The initial hydrolysis of pectin was slower than that of sodium polypectate, *e.g.*, after 2 hours, twice as many reducing groups were liberated from the pectate as from the pectin solution. Also, the initial activity of dialysed PG on pectin is low, only about a third of that on sodium polypectate.

In summary, it may be said that *R. solani* produces a PG which actively hydrolyses both pectin and sodium polypectate and that dialysis of the crude preparations seems to alter the properties of the enzyme solution.

(2) *Chromatographic study*.—PG activity was also demonstrated by chromatographic detection of the breakdown products of the enzyme hydrolysis of pectic substances. The enzyme/substrate mixture were as follows:

1% pectin, Na-pectate or Na-polypectate solution at pH 4·0	5 ml.
Veronal buffer at pH 4·0	2 ml.
Dialysed enzyme solution	2 ml.
Distilled water	1 ml.

They were incubated at 25° C. and 1·5 ml. samples were taken immediately (0) and 2, 4, 8 24 and 48 hours after adding the enzymes. Toluene was added after 8 hours to prevent contamination.

Each sample was placed in boiling water for 5 minutes to stop enzyme action and stored at −16° C. until all samples were ready. The following were placed on spots 2 cm. apart on Whatman No. 1 filter-paper.

Spot	Quantity	Enzyme/substrate mixture
1	1×0·0003 g.	1% galacturonic acid + 1% glucose solution.
2–4	5×0·0003 g.	0 hour samples of three reaction mixtures.
5–7	5×0·0003 g.	2 ,, ,, ,, ,,
8–10	5×0·0003 g.	4 ,, ,, ,, ,,
11–13	5×0·0003 g.	8 ,, ,, ,, ,,

Spot	Quantity	Enzyme/substrate mixture
14	1×0·0003 g.	1% galacturonic acid + 1% glucose solution.
15–17	5×0·0003 g.	24–hour samples of three reaction mixtures.
18–20	5×0·0003 g.	48 „ „ „ „
21	1×0·0003 g.	1% galacturonic acid + 1% glucose solution.
22–24	2·5×0·0003 g.	1% three substrates — enzyme.
25	1×0·0003 g.	Dialysed enzyme.
26	1×0·0003 g.	1% galacturonic acid + 1% glucose solution.

The following solvent mixture was used:

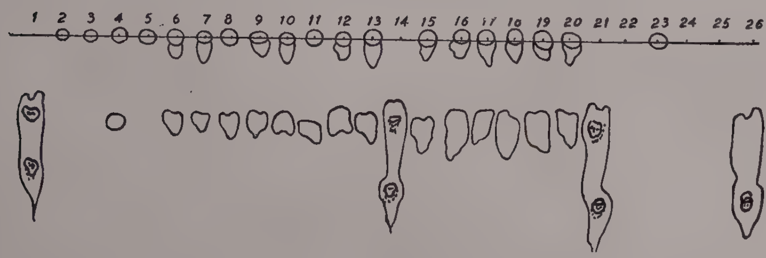
n-Butyl alcohol	40 ml.
Glacial acetic acid	10 ml.
Distilled water	50 ml.

The lower layer was placed at the bottom of the chromatographic cabinet. The filter-paper was left in the cabinet for 6 hours before the upper fraction of the solvent mixture was poured into the trough and allowed to irrigate the paper for 48 hours. The paper was then removed to dry in air. It was then sprayed with the following mixture:

Benzidine	0·5 g.
Glacial acetic acid	10·0 ml.
45% trichloro-acetic acid	10·0 ml.
95% ethanol	100·0 ml.

After heating at 80–100° C. for 5 minutes the positions of the spots of the reducing compounds were revealed. The results are shown in Text-Fig. 1.

The results showed that the enzyme action on the three substrates was similar in that galacturonic acid was produced in each case, after 12, 24 and 48 hours, the spots increasing in size and intensity. There seemed to be some difference in the appearance of intermediate compounds. No intermediate compounds were formed after 8 hours



TEXT-FIG. 1. Chromatographic separation of breakdown products of pectic materials.

Spots: 1, 14, 21 and 26 = galacturonic acid and glucose.
2, 5, 8, 11, 15 and 18 = pectin/enzyme solutions.
3, 6, 9, 12, 16 and 19 = sodium pectate/enzyme solutions.
4, 7, 10, 13, 17 and 20 = sodium polypectate/enzyme solutions, 22—pectin, 23—sodium pectate, 24—sodium polypectate, 25—dialysed enzyme.

following the breakdown of pectin. But in the case of Na-polypectate and Na-pectate, even after 2 hours' hydrolysis, spots appeared between the galacturonic acid spot and the basal line; these spots persisted and became more intense with further hydrolysis. These intermediate spots were present even after 48 hours. Similar intermediates were produced from pectin only after 24 hours' hydrolysis. The results indicate that the enzymes secreted by *R. solani* act upon esterified and de-esterified pectic substances differently during the intitial stages of hydrolysis but that the products of breakdown are similar after 24 hours' hydrolysis.

SUMMARY

While analysing the pectic enzyme system of *R. solani*, it was found that filtrates from its cultures contain a number of other pectic enzymes. The presence of pectinesterase was detected by the measurement of the COOH groups released as a result of de-esterification of pectin or pectinic acid.

In addition, the polygalacturonase activity of the culture filtrate of *R. solani* was also found quite active when the hydrolysis of pectin and sodium polypectate was followed by measuring reducing groups. Chromatographic analysis also confirmed the presence of active PG in the filtrate. A difference in action on pectin, sodium pectate and sodium polypectate was found in the production of intermediate products late in the hydrolysis of pectin and early in the hydrolysis of the other pectic compounds and indicates that either different enzymes are involved in this action or that PG behaves differently with different substrates.

ACKNOWLEDGEMENT

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SOME RECENTLY INTRODUCED WILD GRASSES OF BIHAR

BY J. G. SRIVASTAVA

National Botanical Gardens, Lucknow

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H. H. HAINES' *Botany of Bihar and Orissa* (1921–25) describes 195 species of wild grasses from Bihar, and about 40 sub-species, varieties and forms. He also described a number of species which he expected to occur in the State.

A study of the literature published prior to Haines' *Botany*, *viz.*, Hooker's *Flora of British India* (1897) and Prain's *Bengal Plants* (1903), which Haines had closely drawn upon, shows that he had overlooked a number of past records. Woodhouse's work (Srivastava, 1954 *b*), which was not known to Haines, has also yielded several new records. A critical study of the old sheets of Bihar grasses in various herbaria of the world, have yielded to Bor (1950, 1952, 1952–53, 1953, 1956) a number of new records being mentioned here.

Blatter and McCann's *The Bombay Grasses* (1935) mentions the distribution in Bihar of one species not mentioned in the *Flora of British India*, *Bengal Plants* or Haines' *Botany* and so does Mitra's *Flowering Plants of Eastern India* (1958).

The literature on floristics and vegetation of Bihar published subsequent to Haines' *Botany*, consisting of two books and some two dozen papers, shows that a large number of wild grasses have moved into Bihar from the neighbouring States.

The present paper tries to bring together all such records of grasses not mentioned in Haines' *Botany*.

The species and varieties of grasses, now being reported from Bihar, can be divided into the following categories:—

1. Records in Hooker's *Flora of British India* (1897) missed by Haines.
2. Records in Prain's *Bengal Plants* (1903) missed by Haines.
3. Species mentioned in later works as occurring in Bihar, records probably obtained by a re-study of the old sheets of Bihar grasses in various Indian herbaria.
4. Records obtained by N. L. Bor by a study of the old sheets of Bihar grasses in various herbaria of the world.

5. Species collected by E. J. Woodhouse in the first decade of the present century and publicised in 1954 (Srivastava, 1954 *b*).
6. Species expected by Haines to occur in Bihar. Collected later on.
7. Species about whose old records Haines was doubtful. Records confirmed by later collections.
8. Species casually mentioned in Haines' *Botany*. Collected later on.
9. Cultivated species of grasses that have now got naturalized in Bihar.
10. Species that have moved into Bihar in the recent years from the neighbouring States.

1. The following records in Hooker's *Flora of British India* (1897) were missed by Haines.

(i) *Coelorhachis clarkei* (Hack.) Blatter and McCann. syn. *Rottboellia clarkei* Hack.—mentioned in *Flora of British India*, p. 156 from Parasnath and Hazaribagh as collected by *Clarke*. Recently collected also from Singhbhum (Sanyal, 1957).

(ii) *Dichanthium annulatum* (Forsk.) Stapf var. *papillosum* (Hook. f.) Srivastava syn. *Andropogon annulatus* Forsk. var. *papillosum* Hook. f. syn. *A. papillosus* Hochst.—mentioned in *Flora of British India*, pp. 195–96 from Parasnath Hill as collected by *Clarke*.

2. The following records in Prain's *Bengal Plants* (1903) were missed by Haines.

(i) *Chrysopogon polyphyllus* (Hack.) Blatter and McCann. syn. *Andropogon polyphyllus* Hack. ex. Hook.f. mentioned in *Bengal Plants*, p. 1205 from Chota Nagpur.

(ii) *Eragrostis tenuifolius* (A. Rich.) Hochst. syn. *Poa tenuifolia* Hochst—mentioned in *Bengal Plants*, p. 1223 from Chota Nagpur.
(iii) *Eleusine verticillata* Roxb.—mentioned in *Bengal Plants*, p. 1229 as occurring in Bihar, also in Mitra's *Flowering Plants of Eastern India*.

(iv) *Themeda triandra* Forsk. syn. *T. imberbis* Cooke; syn. *Anthisteria imberbis* Retz.—mentioned in *Bengal Plants*, p. 1207 from Chota Nagpur. Though Haines fully described this plant, he omitted to give the locality. Lately collected from the Parasnath Hills (Srivastava, 1955).

3. The following species have been mentioned in later works as occurring in Bihar, the record probably obtained by a re-study of the old sheets of Bihar grasses in Indian herbaria.

(i) *Andropogon pumilus* Roxb.—mentioned in Blatter and McCann's *Bombay Grasses* as occurring in Bihar. Recently collected from Rajgir and Mandhum (Srivastava, 1959 *b*).

(ii) *Chloris myosuroides* Hook.f.—mentioned in Majumdar's *Studies on the Grasses of the* 24-*Parganas*, p. 40 as occurring in Chota Nagpur.

4. The following records have been obtained by N. L. Bor by a re-study of the old sheets of Bihar grasses in various herbaria of the world.

(i) *Digitaria presleii* (Kunth.) Henrard mentioned in Bor's—*The Genus Digitaria Heist in India and Burma* (1955) *from Bihar*. The records are Parasnath *Clarke*, Purulia *Clarke* and Lohardagga *Gamble*.

(ii) *Microstegium monanthum* A. Camus. syn. *Pollinia monantha* Nees—mentioned by Bor in *The Genus Microstegium in India and Burma* (1952) as occurring on Parasnath Hill *Clarke*. Recently collected from Singhbhum (Sanyal in Mooney, 1950) and Parasnath Hill (Srivastava, 1955).

(iii) *Ischaemum dutheii* Stapf.—Bor publicised this species in *Two New Species of Ischaemum* (1950). The records are Lohardagga *Clarke*. Netarhat *Haines* and Singhbhum *Haines*.

(iv) *Cymbopogon pendulous* (Nees ex Steud.) Wats. ex Atkins. syn. *Andropogon pendulous* Nees—Collected by Burkill in 1911 from Purnea and Bhatgaon (Bor, 1952–53). Recently collected also from Colgong (Srivastava, 1959 *b*).

5. The following species not mentioned in Haines' *Botany*, had been collected by E. J. Woodhouse from Bihar in the first decade of the present century and were publicised in 1954 (Srivastava, 1954 *b*).

(i) *Crypsis schoenoides* (Linn.) Link. syn. *Heleochloa schoenoides* Host.—This plant was collected by Woodhouse from Sabour in 1908. Recently collected from Patna (Srivastava, 1954 *a*). Muzaffarpur (Srivastava, 1958 *a*), Chapra diara and Bhagalpur (Srivastava, 1959 *b*), all places on the bank of the Ganga River, therefore, the plant was probably brought by the river from the Western Himalayas (F.B.I.) or from the upper Gangetic Plains (Raizada, 1954).

(ii) *Paspalidium geminatum* (Forsk.) Stapf. syn. *Panicum paspaloides* Pers. syn. *P. fluitans* Retz.—This plant was collected by Woodhouse from Sabour in 1911, possibly brought by the Ganga River from the upper Gangetic Plains (F.B.I.).

6. The following species were expected by Haines to occur in Bihar. They have been collected later on:

(i) *Arundinella nepalensis* Trin. syn. *A. braziliensis* Hook. f. non Raddi.—This species was collected from Bhikhna thoree in Champaran District on border of Nepal (Srivastava, 1959 *b*).

(ii) *Brachiaria setigera* (Retz.) Hubbard. syn. *Urochloa setigera* Stapf.—This plant has been collected from Patna (Srivastava, 1954 *a*) and Purnea (Srivastava, 1956 *a*).

(iii) *Eragrostis ciliaris* (Linn.) Link.—This plant has been collected from the Parasnath Hills (Srivastava, 1955), Kodarma and Hazaribagh (Srivastava, 1958 *b*) and Chandwa (Srivastava, 1959 *b*).

(iv) *Ophiuros megaphyllus* Stapf. in Haines' *Botany of Bihar and Orissa* syn. *O. corymbosus* Gaertn.—This species has been collected from Panchet forest division in Singhbhum District (Sanyal in Mooney, 1950).

7. The following species, about whose old records in Bihar, Haines was not quite sure, have been collected in recent years.

(i) *Chloris montana* Roxb.—Recorded in Prain's *Bengal Plants from Western Bihar* but whose specimens Haines could not find in the Calcutta herbarium or at Kew, now collected from Hazaribagh District (Srivastava, 1958 *b*).

(ii) *Sporobolus elongatus* R.Br. syn. *S. indicus* R.Br.—Haines was not quite sure if the specimen collected by Campbell from Manbhum was of this species. Now collected from Ranchi (Bressers, 1951) and Parasnath hills (Bharadwaja, 1958).

8. The following species, casually mentioned in Haines' *Botany*, have been collected now from Bihar.

(i) *Echinochloa stagnina* (Retz.) Beauv. syn. *Panicum crus-galli* Linn. var. *stagnina* Trin.—mentioned in Haines' *Botany* just casually. Now collected from Patna (Srivastava, 1954 *a*).

9. The following species, originally cultivated, have now got naturalized in Bihar.

(i) *Amphilophis odorata* A. Camus. syn. *Andropogon odoratus* Lisboa. —A plant of the Deccan Peninsula, that was probably introduced along the Eastern Railway in Patna and along the Patna Sone canal. Now it has got naturalized at both the places (Srivastava, 1954 *a* and 1956 *b*).

(ii) *Sclerostachya fusca* (Roxb.) A. Camus. syn. *Saccharum fuscum* Roxb.—A species of the Sal forests in Terai region, probably introduced in the "Jalla" area of Patna town and in Muzaffarpur District to form rows to demarcate the submerged paddy fields from one another. Now it has got naturalized in both places (Srivastava, 1954 *a* and 1958 *a*).

10. The following species have moved into Bihar in recent years from some of the neighbouring States.

(i) *Arthraxon sub-muticus* Hochst. syn. *Andropogon sub-muticus* Steud. syn. *Batratherum sub-muticum* Nees.—This species is a native of the western Himalayas from Garhwal to Central Nepal (F.B.I.). Now collected from Kodarma in Bihar (Srivastava, 1959 *b*).

(ii) *Cenchrus ciliaris* Linn. syn. *C. pennisetiformis* Hochst. syn. *Pennisetum cenchroides* Rich.—This plant is found in the plains and the low hills of Western India from Kashmir to the upper Gangetic plains and southwards (F.B.I.). Also found in Madras Presidency

(Fischer, 1939) and Western Uttar Pradesh (Bor, 1947). Now collected from Patna (Srivastava, 1956 *a*) and Parasnath Hills (Bharadwaja, 1958).

(iii) *Centotheca latifolia* (Osb.) Trin. syn. *C. lappacea* Desv. syn. *Holcus latifolius* Osbeck. This species is distributed in tropical Sikkim Himalayas, Assam, Duars, east and north Bengal (F.B.I.). Also found in Madras Presidency (Fischer, 1939), Bombay Presidency (Blatter and McCann, 1935). Bamra, Athgarh and Nayagarh States in Orissa (Mooney, 1950). Now collected from various forest divisions of Singhbhum District (Sanyal 1957).

(iv) *Chrysopogon gryllus* (Linn.) Trin. syn. *Andropogon gryllus* Linn.—Distributed in temperate Himalayas from Kashmir to Sikkim at 4,000 to 9,000 ft. and the Khasia hills 4,000 to 5,000 ft. (F.B.I.). Also found in Bombay Presidency (Blatter and McCann, 1935), north-west and south-west Uttar Pradesh (Bor, 1947), the Gangetic Plains (Raizada, 1954), Hills of Assam (Bor, 1936). Now collected in Singhbhum (Mooney, 1950) and Parasanth Hills (Srivastava, 1955).

(v) *Cymbopogon caesius* (Nees) Stapf. syn. *Andropogon caesius* Nees; syn. *Andropogon schoenanthus* Linn. var. *caesius* Hack.—It is distributed throughout the hotter parts of India (F.B.I.). Also found in various parts of the Madras Presidency (Fischer, 1939), in Bombay and Gujrat (Blatter and McCann, 1935). Now collected from Parasnath Hill (Srivastava, 1955).

(vi) *Coelachne simpliuscula* Munro ex Benth. syn. *C. pulchella* R.Br. var. *simpliuscula* F.B.I.—It is distributed in Khasia and Naga Hills, Nilgiri Hills and Ceylon (F.B.I.). Also found in various parts of the Madras Presidency (Fischer, 1939) and Kalahandi and Sarguja in Orissa (Mooney, 1950). Now collected from Singhbhum in Bihar (Sanyal in Mooney, 1950).

(vii) *Cyrtococcum oxyphyllum* (Hochst) Stapf. syn. *Panicum oxyphyllum* Hochst; syn. *C. pilipes* A. Camus; syn. *P. pilipes* Nees *et* Arn.—It is distributed in Sikkim terai, Khasia Hills, Madhya Pradesh, Nilgiri Hills and Ceylon (F.B.I.). Also found in various parts of the Madras Presidency (Fischer, 1939), various parts of the Bombay Presidency (Blatter and McCann, 1935) and Kalahandi State in Orissa (Mooney, 1950). Now collected from Singhbhum District in Bihar (Mooney, 1950).

(viii) *Cyrtococcum patens* (Linn.) A. Camus, syn. *Panicum patens* Linn.—It is found throughout India from the lower Himalayas in Garhwal to Sikkim and the Khasia Hills (F.B.I.). Also found in the upper Gangetic plains (Raizada, 1954), all over Assam (Bor, 1936). Bombay (Blatter and McCann, 1935), all over Eastern India (Mitra, 1958), and Narsinghpur and Jashpur States in Orissa (Mooney, 1950). Now collected from Singhbhum in Bihar (Sanyal, 1957).

(ix) *Lolium perenne* Linn.—It is distributed in Western Tibet and Sikkim Himalayas (F.B.I.). Also found in Khasia Hills (Mitra, 1958), introduced and naturalized in Assam (Bor, 1936), Ooty and Pulney Hills (Fischer, 1939). In Bihar now collected in Purnea (Srivastava, 1956 *a*).

(x) *Isachne albens* Trin.—Distributed in temperate and sub-tropical Himalayas and the Khasia Hills (F.B.I.). Also very common in Assam up to 4,500 ft. (Bor, 1936). In Bihar collected in the Singhbhum District (Sanyal in Mooney, 1950).

(xi) *Lolium temulentum* Linn.—This species is distributed in the upper Gangetic plains, the Punjab, Sind and Western Himalayas (F.B.I.). Also found in Shillong (Mitra, 1958). In Bihar collected in Patna (Srivastava, 1954 *a*).

(xii) *Panicum hydaspicum* Edgew.—This plant is distributed in the Punjab, upper Gangetic plains and Central India (F.B.I.). In Bihar collected from Singhbhum District (Sanyal in Mooney, 1950).

(xiii) *Paspalum distichum* Linn. syn. *P. vaginatum* Sw.—It is distributed in north-west India, Sunderbans and Carnatics (F.B.I.). Also found in the Madras Presidency (Fischer, 1939), Bombay Presidency (Blatter and McCann, 1935), upper Gangetic plains (Raizada, 1954), plains of Assam (Bor, 1936), 24-Parganas (Majumdar, 1956), Agra District (Bharadwaja *et al.*, 1956). In Bihar collected in Patna (Srivastava, 1956 *b*), Sahebgunj (Sanyal, 1957), and Muzaffarpur, (Srivastava, 1958 *a*), all places lying on the bank of the Ganga River, the plant was apparently therefore brought by the river from the west.

(xiv) *Phalaris minor* Retz.—Distributed in the plains of upper India and the sub-tropical Himalayas from Kashmir to Nepal (F.B.I.). Also found in the upper Gangetic plains (Raizada, 1954). In Bihar collected from the Patna-Chapra diara (Srivastava, 1954 *a*) and Bhagalpur (Srivastava, 1959 *b*).

(xv) *Pennisetum orientale* Rich. var. *triflorum* Stapf.—Mentioned in Hooker's *Flora of British India* without any locality. In Bihar collected from the Parasanth Hills (Srivastava, 1955).

(xvi) *Pogonatherum crinitum* Kunth. syn. *Ischaemum crinitum* Trin. syn. *Andropogon crinitum* Thunb.—This species is distributed throughout India, usually at low levels, and in hotter places than *P. saccharioides* (F.B.I.). Common in Assam in shady places (Bor, 1936), Western Ghats, Mysore, etc. (Blatter and McCann, 1935). In Bihar collected from Singhbhum and Ranchi (Sanyal in Mooney, 1950) and Parasnath Hills (Srivastava, 1955).

(xvii) *Pseudoraphis brunoniana* Griff. syn. *P. aspera* (Koen.) Pilger; syn. *Chamaeraphis spinescens* Poir var. *brunoniana* F.B.I.—This species is found in lower Bengal (F.B.I.), Madras Presidency (Fischer, 1939), Bombay Presidency (Blatter and McCann, 1935), upper Gangetic plains (Raizada, 1954), Sylhet and Mymensingh (Bor, 1936), Narsinghpur and Kalahandi (Mooney, 1950). In Bihar collected from Patna (Srivastava, 1954 *a*), Purnea (Srivastava, 1956 *a*) and Hazaribagh (Srivastava, 1958 *b*).

(xviii) *Erianthus chrysothrix* Hack. syn. *Saccharum longifolium* Munro—This species is distributed in Khasia and Naga Hills (F.B.I.). In Bihar collected from Singhbhum District (Sanyal in Mooney, 1950).

(xix) *Themeda villosa* (Poir) Dur. *et* Jack. syn. *Anthisteria villosa* Poir; syn. *A. gigantea* Cav. subsp. *villosa* Hack.—This plant is distributed in Assam, Khasia Hills, Malacca and Java (F.B.I.). Also found in the upper Gangetic plains (Raizada, 1954), Bamra in Orissa (Mooney, 1950). In Bihar recorded only from the Parasnath Hills (Mukerjee, 1956).

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